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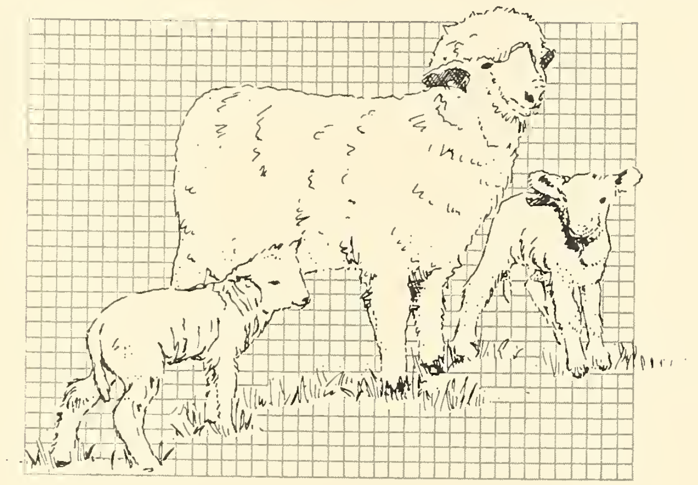
Roman L. Hruska U.S. Meat Animal Research Center in Cooperation with University of Nebraska College of Agriculture, the Agricultural Experiment Station



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CONTENTS

ROMAN L. HRUSKA U.S. MEAT ANIMAL RESEARCH CENTER[1]

1. **Overview of Center:** The U.S. Meat Animal Research Center (MARC) was authorized by Congress on June 16, 1964, thereby creating a single facility that provides an unusual opportunity for making major contributions to the solution of problems facing the U.S. livestock industry. Development of the 35,000-acre facility started in the spring of 1966 and is continuing at the present time. Phase I construction, consisting of an office-laboratory building for intensive investigations, was completed in January 1971. These facilities provide a physical plant for 42 scientists and about 200 support personnel. Phase II construction, consisting of the Meats Research Laboratory and Agricultural Engineering Building, was completed in October 1977 and provides a physical plant for 25 scientists and about 60 support personnel. Phase III construction will provide facilities for a comprehensive research program of producing, harvesting, handling, storing, and using forages in livestock production systems. Approximately 35 additional scientists and 65 support personnel will be required for this phase. Currently, one-third of the scientific staffing is completed.

Approximately 50 percent of the research program is devoted to beef cattle, 30 percent to swine and 20 percent to sheep. Current research program objectives require breeding-age female populations of approximately 7,000 cattle (9 breeds), 4,000 sheep (8 breeds) and 550 swine litters (8 breeds) per year.

The research program at the Center is organized on a multidisciplinary basis and is directed toward providing new technology for the U.S. livestock industry by extending investigations into new areas not now being adequately studied. The research program complements research conducted elsewhere by the U.S. Department of Agriculture and is cooperative with the Nebraska Agricultural Experiment Station and other land grant university agricultural experiment stations throughout the country.

On October 10, 1978, the President signed into law a bill renaming the U.S. Meat Animal Research Center the Roman L. Hruska U.S. Meat Animal Research Center. The purpose of the bill was to honor former Nebraska Senator Roman L. Hruska for "his efforts in the establishment of a centralized Federal facility for the research, development, and study of meat animal production in the United States."

[1]Agricultural Research Service, U.S. Department of Agriculture, the University of Nebraska, and other cooperating land grant universities.

2. **Overview of Sheep Research Program:** MARC's sheep research program places the highest priority on the development of intensive and semi-intensive sheep reproduction system technology capable of having an immediate impact on the sheep industry. Although the program is largely oriented towards fundamental research, emphasis is placed on the generation of technology that can be practically implemented by small farmers and commercial sheep producers alike within a relatively short time frame. Specific research efforts are not oriented toward wool production problems because of research efforts relating to wool in State agricultural experiment stations and other USDA research centers.

The sheep research program is organized on a multidisciplinary basis with the focus on the solution of specific problems that represent the greatest technological constraints to improving production efficiency and product desirability. The program is also designed to complement existing domestic and international research programs in the development of sheep production technology.

The contents in this report represent a cross section of our sheep research program at the present time. Since some of the projects from which results are reported are still in progress, the preliminary nature of some of the results must be recognized. However, it is our opinion that information useful to the industry should be provided at the earliest possible time. Progress reports of this nature will be released periodically to make current results available to the sheep industry.

For the reader's convenience, the table of contents of this report is organized by disciplinary unit which is taking the lead in each specific problem area. The articles within the body of the report are arranged as they most closely relate in subject mattter.

3. **Appreciation:** I want to express my appreciation to Margie McAlhany, MARC Information Officer, and Mike Wallace, Sheep Operations Manager, for serving as coeditors of this report. I also want to thank Linda Kelly for proofreading the report and Doris Aspegren for preparation of the final copy. These individuals have contributed many hours to the completion of this report.

Robert R. Oltjen

Robert R. Oltjen, Director
Roman L. Hruska U.S. Meat
Animal Research Center

Standard Flock Management

Mike H. Wallace, William G. Kvasnicka, Robert B. Anderson and Carrol D. Reutzel[1]

Eleven thousand sheep and lambs comprise the research flock at the Roman L. Hruska U.S. Meat Animal Research Center. Even though they may be on as many as 20 experiments at any one time and are handled under various management schemes by different shepherds, some management practices have been standardized. The Center has approximately 5,000 ewes lambing throughout the year in lambing facilities varying from slotted floor confinement to conventional drylot shed lambing. Although experimental protocol and type of facility dictate variations, some standardized procedures are in practice.

Four to six weeks before lambing, ewes are sheared, drenched with Levamisol-HC1, vaccinated for Types C and D enterotoxemia and given an injection of vitamins A, D, and E. At this time, ewes are switched from a maintenance ration to the late gestation ration (see Table 1). During the last trimester (four to six weeks) of pregnancy, ewes are closely observed for signs of ketosis (lambing paralysis). A ewe that is a suspect is diagnosed by the use of ketone test strips. Ketones can be detected in the urine before irreversible damage occurs. The testing procedure is relatively simple and inexpensive.

When the first lamb in a flock is born, all ewes are switched to the lactation ration (Table 1), which has a higher energy density.

At parturition lamb navels are bathed in a 7 percent iodine solution and lambs are vaccinated intranasally for PI_3-IBR. A ewe and her lambs are individually penned or "jugged," and her udder is checked for milk supply and function. Ewes and lambs remain jugged for about two days and are observed for nutritional status of the lambs. Lambs which are not receiving an adequate supply of milk are fed via stomach tube two to four ounces of bovine colostrum, as needed.

Lambs in excess of the ewe's ability to rear are removed for artificial rearing or are fostered onto another ewe shortly after tagging (one to two days of age). Tagging involves weighing and ear-tagging and paint-branding lambs and ewes. Ewes and lambs are paint branded with consecutive numbers starting with the first ewe lambing in a flock. Fostering is accomplished by use of the English fostering crate.

Lambs to be artificially reared are placed in the nursery facility at one to two days of age. The 600 lambs entered yearly into the nursery are given two to four ounces of bovine colostrum and trained to the use of nipples. Lambs are self-fed on a commercially prepared ewe milk replacer and given free-choice access to a nursery ration (Table 2) until weaning at about four weeks of age. Lambs are docked, vaccinated for sore mouth and vaccinated with Types C and D overeating anti-toxin at three to seven days of age. After weaning, lambs begin an adaptation to the less-controlled environment to be encountered when they return to the flock of lambs in which they were born.

At about two days postpartum, ewe-lamb(s) pairs are moved to a "mixing" pen with 5 to 15 other pairs of about the same age. They remain in this group and are closely observed for signs of mis-mothering and health problems until docking with emasculators at about seven days of age. Two to three days after docking, ewes and lambs in mixing pens are moved to rearing pens containing 15 to 70 pairs. Pairs will remain in their rearing pens until weaning at 42 to 56 days of age, or until they are moved to pasture at 30 days of age (depending on time of year, weather, prescribed weaning age, etc.). Pastured lambs are routinely weaned at 70 days of age. All lambs are given free access to creep feed (Table 2) while in the rearing pens or on pasture.

Weaning procedures vary considerably by flock, age of lambs and type of rearing facility. In general, the ewe's ration is changed to maintenance levels a few days preweaning and ewes are not fed on weaning day. Ewes and lambs are separated, lambs are weighed, given an injection of vitamin A, D and E, vaccinated against Clostridias, sorted by sex and placed back in rearing pens. Lambs weaned off pasture are also drenched with Levamisol-HC1 and placed in drylot. Ewes are drenched with fenbendazole and individuals are culled. A ewe is culled for: 1) mastitis or any udder dysfunction; 2) vaginal or uterine prolapse; 3) severe emaciation; 4) severe over- or underbite; 5) broken mouth; 6) chronic respiratory problem; 7) rupture; 8) failing to lamb or rear a lamb in two consecutive lambing seasons; or 9) failing to keep up with the flock movement during a "normal" drive. These ewes are sold as slaughter culls. The sound "keeper" ewes are placed on pasture.

After a two-week postweaning adjustment period, lambs may be moved to or put on various research studies. Lambs are routinely self-fed pelleted complete rations plus limited quantities of hay.

During the summer, or between weaning and breeding, all ewes are drenched with Levamisol-HC1, shower-dipped for external parasites, and feet are trimmed and bathed in a zinc sulfate solution.

Ewe lambs designated to be saved for replacement stock are sheared; vaccinated against enzootic abortion, vibrio and BVD; and moved to pasture at five to six months of age. They are fed limited quantities of concentrates. All replacement ewe lambs are bred at seven months to lamb at 12 months of age.

All ewes are drenched with phenothiazine with arsenic and vaccinated for vibriosis, enzootic abortion and BVD prior to the 30- to 35-day breeding period.

Most matings are done on a single-sire basis to maintain sire identity.

MARC's 350 stud bucks are sheared during late May and drenched with Levamisol-HC1 during December and July and fenbendazole in September. Rams are also drenched with phenothiazine-arsenate and vaccinated against Clostridias, BVD and PI_3-IBR in March. Testicles are palpated for abnormalities at time of drenching. Feet are trimmed and bathed twice yearly. Rams which have abnormalities of feet/legs, mouth structure or testicles or repeatedly fail to have viable semen tests are sold as slaughter culls. Yearling and mature rams are managed in separate flocks to limit spread of *Brucella ovis* (epididymitis).

The Center's sheep research program places the highest priority on the development of intensive and semi-intensive sheep production systems technology capable of having an immediate impact on the sheep industry. However, it is the duty and responsibility of the shepherds to ensure that the animals are available and healthy for the research projects. Only through disciplined preventive programs such as the one outlined here may the ultimate objective — helping the industry produce red meat more efficiently — be reached.

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[1]Wallace is the sheep operations manager; Kvasnicka is the herd health veterinarian; and Anderson and Reutzel are agricultural research technicians, MARC.

Table 1.—Breeding sheep rations utilized

	Corn Silage	Mineral Supplement[1]	Soybean Meal	Corn	Chopped Alfalfa Hay
	pct				
Maintenance Ration 9.6 pct Crude Protein	98.00				
Maintenance Ration 9.6 pct Crude Protein 68 pct T.D.N.	98.00	0.75	1.25		
Late Gestation Ration 11.9 pct Crude Protein 67 pct T.D.N.	80.00	0.75	2.00	6.50	10.70
Lactation Ration 13.8 pct Crude Protein 72 pct T.D.N.	72.00	0.70	4.80	13.40	10.00

[1]Mineral Supplement: 35 percent trace mineralized salt, 35 percent steamed bone meal, 25 percent limestone, 5 percent sodium sulfate, plus vitamins A, D and E. Pasture Mineral Supplement: 65 percent trace mineralized salt, 16 percent steamed bone meal, 16 percent limestone and 3 percent mineral oil.

Table 2.—Complete self-fed lamb rations utilized

	Alfalfa	Concentrate[1]	Molasses
	pct		
Lamb Creep, Pelleted (Lambs up to 60 lb) 17 pct Crude Protein 79 pct T.D.N.	29	80	
Lamb Growing Rations, Pelleted (Lambs 60-80 lb and replacement stock to 7 months) 15 pct Crude Protein 70 pct T.D.N.	45	55	
Lamb Finishing Ration, Pelleted (80 lb to slaughter) 13 pct Crude Protein 80 pct T.D.N.	20	80	
Dry Nursery Ration, Ground-mixed (2 days to 28 days for artificially reared lambs) 20 pct Crude Protein 79 pct T.D.N.	20	73	7

[1]Concentrate portion includes corn and soybean meal in proportions to meet protein and energy requirements. The following is also included as a portion of the total ration: 5 percent trace mineralized salt .5 percent steamed bone meal, 1.0 percent limestone, .5 percent ammonium chloride plus vitamins A, D and E supplement.

Sheep Research Facilities

Mike H. Wallace, Robert B. Anderson and Carrol D. Reutzel[1]

Description of Facilities and Utilization

The sheep research program at MARC utilizes 1,700 acres of pasture consisting of 160 acres of irrigated brome, 240 acres of warm season perennial and 1,300 acres of dryland brome. Up to 4,000 head of ewes are maintained on various levels and types of management to fit research requirements. About 400 purebred and crossbred stud rams are maintained and studied, and over 6,000 head of lambs are produced, fed and studied yearly.

Eighteen facilities specifically designed for animal handling efficiency and animal comfort and welfare are utilized. These include:

- Building 37 — A 1,000-head raised slotted floor lamb feedlot.
- Building 36 — A 900-ewe raised slotted floor lambing facility.
- Buildings 31, 32 and 33 — Three 380- to 420-head drylot lambing and and feedlot facilities.
- Building 30 — Intensive lamb research projects, automated feed-monitoring devices, surgery and 250-head artificial rearing facility.
- Buildings 34 and 35 — Two 900-head ewe wintering and lamb feedlot facilities.
- Building 38 — Sale area, covered sorting facility and shearing facility.
- Pole Sheds 1 and 4 — Two 500-head ewe lambing and lamb feedlot facilities.
- Section 37D — Includes 6 "igloos" modified for ram housing and photoperiod control and an enclosed sorting and handling facility.

The levels, breeds and types of management currently utilized are:

- 420 head of half-Finn ewes shed-lambed yearly in Building 32 and reared on pasture primarily for physiology studies.
- 200 head of half-Finn ewes lambed on an 8-month accelerated schedule in Building 36, producing lambs for short-term nutrition, physiology and meats studies.
- 450 head of half-Columbia X quarter-Suffolk X quarter-Hampshire ewes lambed annually at Pole Shed 4, primarily utilized for genetics and breeding studies.
- 500 head of Suffolk ewes lambed annually at Pole Shed 1, used for genetics and breeding studies.
- 320 head of half-Finn X quarter-Dorset X quarter-Rambouillet ewes bred for various 6-month lambing schedules at Building 31.
- 320 head of half-Finn and Rambouillet ewes lambed annually in Building 33, primarily utilized for nutrition studies.
- 750 head of Finn, Targhee, Suffolk and half-Finn X quarter-Suffolk X quarter-Targhee ewes lambed annually in Building 36, primarily utilized for genetics and breeding studies.
- 1,000 head of Finn, Rambouillet, Dorset and half-Finn X quarter-Dorset X quarter-Rambouillet lambed on an 8-month accelerated schedule in Building 36, primarily utilized for genetics and breeding studies.

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[1]Wallace is the sheep operations manager, and Anderson and Reutzel are agricultural research technicians, MARC.

Comparison of Border Leicester and Finnsheep Crosses: I. Survival, Growth and Carcass Traits of Crossbred Lambs

Gordon E. Dickerson, Aiad F. Magid, Vern B. Swanson, James S. Brinks and Gerald M. Smith[1]

Introduction

Crosses of the Border Leicester (BL) sheep of Scotland are used extensively in other countries for production of long-staple medium wool and crossbred market lambs. They have not been used widely in the U.S., although BL crossbred ewes evaluated at the North Dakota State University Experiment Station were promising in lambing rate, milk production and fleece yield. Thus, an experiment was conducted at MARC to compare BL crosses with prolific Finnsheep (F) crosses, especially as commercial ewes to be mated with rams of meat breeds for production of market lambs. The first phase of the experiment compared viability, growth and carcass merit of the BL- and F-sired lambs.

Procedure

Six BL rams from two North Dakota flocks and eleven F rams from the MARC flock were used. Hampshire, Rambouillet, Targhee and half-F ewes were assigned randomly within breed and age to either BL or F rams for breeding during November of 1972 and December-January of 1973-74. A total of 334 lambs were produced in the spring of 1973 and 305 in 1974.

During gestation, ewes were on pasture with supplemental alfalfa hay, and one lb grain/head/day was added during the last 30 days. Ewes were fed corn silage *ad libitum* in drylot for one week immediately before lambing. Immediately after lambing, each ewe and her lamb(s) were moved into 4 ft x 5 ft pens with heat lamps for 24 to 48h. A few weak lambs and lambs in excess of two per ewe were artificially reared on milk replacer and creep feed from day 1 or 2. About 2 days after lambing, ewes and lambs were grouped by lambing date into larger pens and continued on corn silage to weaning. When the youngest lambs in a pen were 5 weeks old, all lambs were weaned. Rams and ewe lambs were then separated and self-fed a 17 percent corn-soy-alfalfa ration in drylots to about 154 days of age.

Lambs were weighed at birth and weaning. Weights were adjusted to constant ages of 70 days (birth weight + 70 x preweaning daily gain) and 154 days (actual weaning weight + postweaning daily gain x days from weaning to 154 days of age). Carcass measurements and grades were obtained for a sample of the 1974 lambs slaughtered at an average liveweight of about 100 lb.

Results

The birth and weaning traits were adjusted for important effects of year, type of birth-rearing, sex and age of dam (Table 1). The half-BL lambs were 0.6 lb heavier at birth than the half-F lambs, but gained 0.04 lb/day less prior to weaning and weighed 1.8 lb less at 70-day weaning. Also, fewer half-BL lambs survived to weaning (54 vs 66 pct). Feedlot gain was similar for half-BL and half-F lambs, but the half-BL lambs weighed 2.8 lb less than the half-F lambs at 22 weeks of age.

The limited carcass information taken at about 100 lb liveweight (Table 2) indicated that the half-BL lambs had more external fat and higher quality leg conformation and maturity grades, but less kidney fat, than the half-F lambs. However, yields of trimmed or of deboned cuts were equal, as predicted from carcass backfat thickness, kidney fat and leg conformation scores.

Performance of first-cross lambs indicated that half-BL lambs were superior in birth weight and carcass grade, but were poorer in preweaning gain and lamb survival and similar in postweaning growth rate and cut yields compared with half-F lambs.

[1]Dickerson is a research geneticist, Genetics and Breeding Unit, MARC, stationed at Lincoln, NE; Magid is on the staff of the University of El-Fateh, Tripoli, Libya (formerly a graduate student at Colorado State University); Swanson is an associate professor and Brinks is a professor of animal science, Colorado State University; and Smith is a consultant, Department of Animal Science, Texas A&M University, College Station, TX (formerly research leader, Production Systems Unit, MARC).

Table 1.—Survival and growth of Border Leicester- and Finnsheep-sired ewe and ram lambs from 2- to 7-yr-old ewes of four breeds in 1973 and 1974[1]

Sire of lambs	Number born	Preweaning weight (lb) Birth	70 days	Daily gain	Alive at weaning (pct)	Feedlot weight (lb) Daily gain	at 22 wk
BL	293	[3]8.8	37.0	[2].39	[3]54	.37	[2]71.8
F	346	8.2	38.8	.43	66	.38	74.6

[1]Dam breeds were Hampshire, Rambouillet, Targhee and half-Finn crosses. Ewes of each breed and age were divided randomly between BL and F sires.
[2] = 5 percent or smaller probabilities of the differences arising by chance errors of sampling.
[3] = 1 percent or smaller probabilities of the differences arising by chance errors of sampling.

Table 2.—Carcass traits of Border Leicester (BL)- and Finnsheep (F)-sired ram lambs born in 1974

Sire of lambs	No. of lambs	Wt (lb)	Leg length (in)	Fat 12th rib (in)	Fat Kidney (pct)	Dressing (pct)	Predicted pct Trimmed cuts	Predicted pct Boned cuts
BL	19	45.0	4.5	[2].08	[1]2.6	51.8	79.2	46.6
F	51	46.3	4.4	.06	3.0	49.6	79.3	46.6

	Grades Yield	Quality	Conformation	Leg	Maturity
BL	2.4	[1]8.7	9.3	9.6	[1]1.1
F	2.4	7.9	8.5	9.1	1.0

[1]5 percent or smaller probabilities of the differences arising by chance errors of sampling.
[2]1 percent or smaller probabilities of the differences arising by chance errors of sampling.

Comparison of Border Leicester and Finnsheep Crosses: II. Productivity of Crossbred Ewes

Gordon E. Dickerson, Aiad F. Magid, Vern B. Swanson, James S. Brinks and Gerald M. Smith[1]

Introduction

Crosses of the Border Leicester (BL) sheep of Scotland have been used extensively in other countries and, to a limited extent, in the U.S. for production of long-staple, medium wool and crossbred market lambs. Recent research at MARC and at state experiment stations has shown that crossbred half- and quarter-Finnsheep (F) ewes have markedly higher lambing rates and lamb crops reared than domestic U.S. crossbred ewes. Thus, an experiment was conducted at MARC to compare usefulness of crossbred half-BL and half-F ewes for commercial wool and market lamb production. This report includes wool and weaned lamb production for three lamb crops from half-BL and half-F ewes in matings with Suffolk rams.

Procedure

All of the half-BL and half-F ewe lambs produced in 1973 and 1974 from crosses with Hampshire, Rambouillet, Targhee and half-F ewes were retained for lambing in May of 1974 and 1975 and in February and March of 1976. Ewes from each of the eight crosses of each birth year were assigned randomly to 6 Suffolk rams for 1974, 13 for 1975 and 11 for 1976 lambing. After weaning, the crossbred ewe lambs were fed *ad libitum* in drylots until breeding age on a 16.8 percent crude protein (CP) diet of about 50 percent corn silage and 50 percent dehydrated alfalfa, plus supplemental soybean meal and minerals. Ewes were then fed *ad libitum* in the breeding pens on alfalfa and a 13 percent CP diet of 60 percent corn silage and 40 percent corn-soybean meal-mineral-vitamin mix during breeding, gestation and lactation.

Lambs were weaned at 4 to 11 weeks of age in July of 1974 and 1975, and at 7 to 10 weeks of age in May of 1976. Lambs had access to a 17 percent CP corn-soybean-alfalfa creep diet in 1974 and 1975 and to a 19 percent CP diet in 1976 from about 3 weeks before until 2 weeks after weaning. Lambs in excess of two per ewe were reared in a nursery from 2 days of age.

All lamb birth and weaning dates and weights and dates of mortality were recorded. Body and fleece weights and condition scores of the crossbred ewes were recorded only once, after lambs were weaned in 1976. Fleeces were evaluated for percentage clean wool, staple length and fineness.

Results

The half-BL ewes were similar in fertility and had slightly less lambing difficulty than the half-F ewes, but dropped 22 percent fewer and weaned 24 percent fewer lambs than the half-F ewes (Table 1), when compared within year and age of ewe. Lambs from the half-BL ewes averaged nearly 20 percent heavier at birth but gained no faster and had slightly more losses to weaning age than lambs from half-F ewes (Table 2). Fewer of the half-BL ewes that lambed weaned one or more lambs (78 vs 86 pct), and total weight of lamb per ewe lambing or per ewe exposed was lower by about 8 percent at birth and by 19 percent at weaning (Table 3) than for half-F ewes.

The half-BL and half-F ewes were similar in body weight after weaning their lambs in May of 1976 at 2 and 3 years of age (Table 4). The half-BL ewes maintained better fleshing than the half-F ewes, as expected from nursing fewer lambs, but they also produced 16 percent more clean wool with a longer staple and coarser grade.

The breed of dam of the crossbred ewes had real effects on ewe body weight, condition, clean fleece yield and wool characters and on preweaning growth and survival of lambs, but not on weight of lamb weaned per ewe lambing. Crossbred ewes from Hampshire dams were heaviest and fattest, but low in fleece yield and staple length and intermediate in wool fineness. Ewes from Targhee and Rambouillet dams approached those from Hampshire dams in body weight and fleshing and were highest in fleece yield. The crossbred ewes from half-F dams (i.e., BL x 1/2-F or F x 1/2-F) were smallest, carried the least fleshing after weaning and produced lighter, longer-staple and coarser fleeces than the other types of crossbred ewes. Lambs from half-Rambouillet ewes were heaviest at birth but poorest in survival, while those from half-F granddams were lightest at birth but best in survival.

The half-BL crossbred ewes clearly weaned at least 20 percent fewer lambs and 20 percent less weight of lamb per ewe exposed than the half-F ewes for the same weight of ewe maintained. However, the half-BL ewes did produce 16 percent heavier fleeces with a longer staple and coarser grade.

[1]Dickerson is a research geneticist, Genetics and Breeding Unit, MARC, stationed at Lincoln, NE; Magid is on the staff of the University of El-Fateh, Tripoli, Libya (formerly a graduate student at Colorado State University); Swanson is an associate professor and Brinks is a professor of animal science, Colorado State University; and Smith is a consultant, Department of Animal Science, Texas A&M University, College Station, TX (formerly research leader, Production Systems Unit, MARC).

Table 1.—Lamb production of half-BL and half-F ewes at 1, 2 and 3 years of age, from matings with Suffolk rams

Breed of ewe	Number of ewe matings	Ewes lambed (pct)	Lambs/100 ewes/lambing: Born	Live	at 4 wk	at 10 wk	Lambing difficulty[1]
Half-BL	192	67	139	136	102	93	1.03
Half-F	228	68	[3]178	[4]177	[4]130	[4]122	[2]1.10

[1]Scored 1 = no problem, 2 = some assistance, 3 = very difficult, 4 = caesarean.
[2]Probability of chance difference of size indicated is less than 5 percent.
[3]Probability of chance difference of size indicated is less than 1 percent.
[4]Probability of chance difference of size indicated is less than 0.1 percent.

Table 2.—Preweaning growth and survival of Suffolk-sired lambs from half-BL and half-F ewes mated to lamb at 1, 2 and 3 years of age

Breed of ewe	Number of lambs		Preweaning wt/lamb (lb)			Surviving to weaning (pct)
	Born	Weaned	Born	Gain/day	70 days	
Half-BL	188	125	[1]8.3	.41	37.0	64
Half-F	284	199	7.0	.40	35.5	69

[1]Probability of chance difference of size indicated is less than 0.1 percent.

Table 3.—Total weight of Suffolk-sired lambs born and weaned from half-BL and half-F ewes mated to lamb at 1, 2 and 3 years of age

Breed of ewe	Ewes lambing		Total weight of lambs (lb)			
			Per ewe lambing		Per ewe exposed	
	No.	Pct weaning lambs	Born	Weaned	Born	Weaned
Half-BL	129	78	11.6	33.0	7.8	22.2
Half-F	156	86	[1]12.4	[2]40.9	[1]8.5	[2]28.0

[1]Probability of chance difference of size indicated is less than 5 percent.
[2]Probability of chance difference of size indicated is less than 1 percent.

Table 4.—Postweaning body weights, condition scores and wool traits for two ages of half-BL and half-F ewes by four breeds of dam

Age of ewe	No. of ewes	Body wt (lb)	Condition score[1]	Fleece wt (lb)		Staple length (in)	Fiber diam (microns)
				Grease	Clean		
2 years	79	114	3.1	[3]6.0	[4]3.9	[4]4.1	[2]29.1
3 years	48	[4]138	[4]3.8	7.0	5.3	4.6	30.5
Sire bred of ewe							
BL	65	127	[2]3.6	6.7	[4]5.0	[4]4.7	[4]31.1
F	62	124	3.3	6.3	4.3	4.0	28.5
Dam breed of ewe							
Hampshire	31	[4]132	[4]3.8	5.8	[4]4.4	[3]4.1	29.8
Rambouillet	36	124	3.4	6.9	5.0	4.5	30.0
Targhee	14	131	3.6	7.0	5.1	4.2	28.3
Half-F	46	116	3.0	6.3	4.1	4.6	31.2

[1]Scale of 1 = emaciated, 2 = thin, 3 = normal, 4 = fleshy, 5 = fat.
[2]Probability of chance difference of size indicated is less than 5 percent.
[3]Probability of chance difference of size indicated is less than 1 percent.
[4]Probability of chance difference of size indicated is less than 0.1 percent.

Comparison of Border Leicester and Finnsheep Crosses: III. Market Lamb and Wool Production Per Ewe

Gordon E. Dickerson, Aiad F. Magid, Vern B. Swanson, James S. Brinks and Gerald M. Smith[1]

Introduction

Crossbred half-Border Leicester (BL) ewes have been used in other countries for production of long-staple, medium wool and market lambs. To evaluate such BL ewes under U.S. conditions, they were compared with half-Finnsheep (F) ewes in an experiment at MARC. In this report, the postweaning growth and carcass merit of Suffolk-sired lambs from half-BL vs half-F ewes is compared and a general summary of their relative lamb and wool production is presented.

Procedure

Postweaning growth and carcass data on 298 Suffolk-sired ewe and ram lambs from half-BL and half-F ewes were recorded for lambs born in May of 1974 and 1975 and in early March of 1976. Lambs were weaned at 8 to 10 weeks of age and then self-fed, in drylot, a ration with equal parts of corn silage and a complete 16 percent CP supplement until slaughter at about 112 lb liveweight and 5 to 7 months of age.

The weaning and final feedlot body weights and ages were used to calculate average daily gain (ADG) and the adjusted 154-day weight (actual weaning weight + ADG x days from preweaning to 154 days of age). Lambs were slaughtered in two groups each year at commercial slaughtering facilities, where carcass weight, measurements and scores were recorded.

Results

Postweaning Growth and Carcass Traits. All comparisons of lambs from half-BL vs half-F ewes were made within the important year, age of ewe and sex classes, and were adjusted for large effects of variation in lamb's age at weaning and days in the feedlot. However, effects of differences in type of birth-rearing were considered as part of total ewe performance and were not adjusted.

Lambs from half-BL and half-F ewes did not differ in feedlot daily gain, weight at 154 days, final slaughter weight or dressing percentage (Table 1). When carcass backfat thickness, kidney fat and leg conformation score (Table 2) were used to predict USDA yield grade and yields of trimmed wholesale cuts and of boned lean cuts, only the slight superiority of lambs from the half-F ewes in yield of boned lean cuts (46.6 vs 46.2 pct) was consistent enough to be considered real.

Carcasses of lambs from half-BL ewes had more external fat but less kidney fat, and, consequently, higher carcass quality and conformation grades (Table 2). However, leg length, maturity grades and fat color were identical for lambs from half-BL and half-F ewes, and leg conformation scores were not consistently better for lambs from half-BL ewes.

Total Market-Lamb and Wool Production Per Ewe. Performance of 187 half-BL and half-F ewes was compared in 420 matings with Suffolk rams for lambing at 1, 2 and 3 yr. of age (Table 3). The half-BL and half-F ewes were almost identical in body size and percentage of ewes lambing. The half-BL ewes dropped 39 fewer and weaned 29 fewer lambs per 100 ewes lambing. The half-BL ewes also weaned 8 lb (19 pct) less and marketed 28.5 lb (22 pct) less total lamb weight than the half-F ewes. However, the half-BL ewes produced 0.7 lb (16 pct) more clean wool with a longer staple but coarser grade than the half-F ewes. Also, carcasses of market lambs from half-BL ewes had more external fat, higher carcass quality and conformation grades, but no greater yield of trimmed or boneless cuts. Thus the major disadvantage of half-BL relative to half-F ewes in lambs weaned per ewe lambing (−24 pct) was only slightly offset by 3 percent faster growth of lambs and 16 percent heavier clean fleece weights from half-BL ewes. The net disadvantage in total value of lamb and wool output per ewe lambing was about −18 percent, assuming that 1 lb of clean fleece = 3 lb of lamb liveweight marketed. This comparison ignores differences in input costs, which would be greater for differences in lamb than in wool output.

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Table 1.—Postweaning growth and carcass yields[1] for Suffolk-sired ewe and ram lambs from half-Border Leicester (BL) and half-Finnsheep (F) ewes

Breed of ewe	No. of lambs	Avg. daily gain[2] (lb)	Weight[2] (lb)		Dressing pct	Yield grade[3]	Predicted cuts, pct of carcass	
			154 d	Slaughter			Trimmed	Boned
Half-Bl	117	.47	77.9	111.7	51.3	3.9	70.5	46.2
Half-F	181	.47	75.4	108.5	51.6	3.8	70.5	[4]46.6

[1]Unadjusted for type of birth-rearing.
[2]From weaning at 8 to 10 weeks to weight nearest to 154 days of age.
[3]USDA yield grade = 1.66 + 6.73 (loin fat, in) + .25 (pct kidney fat) − .05 (leg conformation score).
[4]Less than 1 percent probability of the difference arising by chance errors of sampling.

Table 2.—Carcass measurements and grades[1] for Suffolk-sired ewe and ram lambs from half-BL and half-F ewes

Breed of ewe	Length leg (in)	Thickness (in) Loin fat	Thickness (in) Body wall[2]	Kidney fat (pct)	Fat color[3]	Carcass grades or scores Maturity[4]	Quality[5]	Conform.[5]	Leg[5]
Half-BL	4.4	[6].22	[6].87	[6]3.3	2.2	1.6	[6]10.9	[6]11.2	11.4
Half-F	4.5	.18	.79	3.9	2.3	1.6	10.5	10.7	11.1

[1]Unadjusted for type of birth-rearing.
[2]Six in from midline at 12-13 rib.
[3]Scale from 1 = very white to 6 = very yellow.
[4]Scale from 1 = very young to 9 = very mature.
[5]Scale from 8 = Average good, 11 = Average choice and 14 = Average prime.
[6]Less than 1 percent probability of the difference arising by chance errors of sampling.

Table 3.—Summary of Suffolk-cross and lamb and wool production from half-BL and half-F ewes

Trait	No. of ewes	Half-BL	Half-F
Ewes lambing, percent	420	[3]67 (99)	68
Lambs/100 lambings			
Born		[5]139 (78)	178
Weaned		[6]93 (76)	122
Lamb weight/ewe lambing, lb[1]	285		
Born		[4]11.6 (94)	12.4
Weaned		[5]33.0 (81)	40.9
At 154 days of age		[5]72.4 (79)	92.0
At slaughter		103.9 (78)	132.4
Ewe weight at 2 and 3 years, lb	127	127 (102)	124
Clean fleece weight, lb	127	[6]5.0 (116)	4.3
Staple length, in	127	[6]4.7 (118)	4.0
Spinning count	127	[6]48 (89)	54
Lamb equivalent/ewe/lambing[2]	285	[6]118.9 (82)	145.3

[1]Unadjusted for type of birth-rearing.
[2]Assuming 1 lb clean fleece = 3 lb lamb slaughter weight.
[3]Relative performance of half-BL relative to half-F ewes, in percentage.
[4]Less than 5 percent probability of the difference arising by chance errors of sampling.
[5]Less than 1 percent probability of the difference arising by chance errors of sampling.
[6]Less than 0.1 percent probability of the difference arising by chance errors of sampling.

Lamb Production and Its Components in Pure Breeds and Composite Lines. I. Seasonal and Other Environmental Effects

Larry D. Young, Neal M. Fogarty and Gordon E. Dickerson[1]

Introduction

The great diversity in performance among breeds of sheep provides an opportunity for choice of breeds and crosses best suited to various production objectives, environments and management systems. Flocks of several sheep breeds and crosses have been evaluated for components of lamb production under both accelerated and annual spring lambing management. Data from these experiments have been analyzed to explore alternative breeding and management approaches for improving efficiency of market lamb production.

This paper reports effects of nursery rearing of lambs, interval between lambings, hormone treatment and season of breeding and their interactions with breeds for components of lamb production. Throughout this paper, year and season refer to lambing time unless specified otherwise.

Procedure

Data for this study were from ewes exposed to lamb from 1976 through 1979. The data included purebred Dorset (D), Finnsheep (F), Rambouillet (R), Suffolk (S), and Targhee (T), and the first three generations of crossbred ewes involved in the development of two composite lines: Composite 1 (C1) = 1/2F,1/4R,1/4D and Composite 2 (C2) = 1/2F,1/4S,1/4T. C1 was developed by reciprocal crossing of 1/2F,1/2R and 1/2F,1/2D ewes and rams. C2 was developed by reciprocal crossing of 1/2F,1/2S and 1/2F,1/2T ewes and rams. Unless otherwise noted, references to C1 and C2 will include the performance of the respective 2-breed cross ewes. A total of 4,219 ewes having a total of 10,959 ewe breeding season records over the 4-year period were included in the analyses.

Two-thirds of the ewes in each season were selected randomly to be exposed to rams for lambing at an 8-month interval, and exposure of the remaining one-third was delayed for lambing at a 12-month interval. Similarly, a random two-thirds of the ewe lambs were exposed for first lambing at 12 months of age and one-third were exposed for first lambing at 16 months of age.

Ewes were exposed to rams for 32 to 38 days in single-sire groups in drylot. Rams were introduced about August 19 for January lambing, November 7 for April lambing, December 17 for May lambing and April 1 for September lambing in 1976 to 1978 and April 26 for September lambing in 1979. All rams were semen tested before use.

In 1976 and 1977, R, D, F, T, C1 and C2 flocks lambed in January, May and September. The same lambing schedule was continued in 1978 and 1979 for R, D, F and C1, but annual April lambing flocks were established for R, F, S, T, C1 and C2.

Approximately one-half of the ewes of each breed group exposed to rams in April for lambing in September of 1976, 1977 and 1978 were subjected to hormone treatment to induce out-of-season fertility.

At 1 or 2 weeks before lambing, depending on udder development, ewes were placed in a lambing barn equipped with a raised, expanded metal floor and were fed corn silage supplemented with corn. Soon after lambing, the ewe and her lamb(s) were moved to a small pen (5 ft x 4 ft) for 1 to 2 days. Weaker lambs in excess of two per ewe were transferred 1 to 2 days after lambing to a nursery for artificial rearing on milk replacer with access to pelleted creep feed. Other lambs that could not be or were not mothered by their dams were also reared in the nursery. Lambs were weaned at 5 to 10 weeks of age, depending on the season and year.

All healthy ewe lambs without gross abnormalities were retained for breeding. Ewes were culled if they: 1) failed to lamb by 2 years of age; 2) failed to lamb at two successive lambings (excluding September); or 3) were more than 7 years of age. Replacement ram lambs were selected from multiple-birth litters on the basis of weight adjusted for age, type of rearing, age of dam and structural soundness.

Statistical analyses were conducted to determine the effects of breed, season and year and their interactions on several reproductive traits. Data were also adjusted for the effects of ewe age.

Seven components of total number and weight of lambs weaned were defined for each ewe exposed: fertility (did or did not give birth to at least one lamb), litter size born, survival to 1 day of age of all lambs born, lambs weaned by the ewe of lambs born alive, lambs weaned by the ewe and in the nursery of all lambs born alive, mean adjusted 42-day weight of lambs weaned on each ewe, and mean adjusted 42-day weight of all suckled and nursery-reared lambs weaned from each ewe.

Results

Nursery-reared lambs: Birth weights for nursery-reared lambs born in January 1977 and in April-May of 1977, 1978 and 1979 were about 1 lb lighter than their dam-reared littermates in C1, C2 and F but did not differ in the heavier D, R, S and T lambs (879 nursery- and 1,062 dam-reared lambs). Survival increased 3.5 percent for each 1 lb increase in birth weight in D, R, S, and T compared with 9.4 percent in C2, 12.8 percent in F and 1.3 percent in C1. However, effects of type of birth (single, twin, etc.) and mean birth weight of littermates on survival of nursery-reared lambs were negligible. Average survival of nursery-reared lambs was higher for F than for other breeds (68 vs 56 pct).

Hormone treatment: Hormone treatment at spring exposure in 1976, 1977 and 1978 increased fertility from 15.8 to 44.2 percent and litter size from 1.59 to 1.79. Fertility was increased less by hormone treatment in F than in the other breeds. The effect of hormone treatment on litter size was essentially the same in all breeds. Over one-half of the treated D and half-F ewes lambed. Hormone treatment did not have a large effect on any of the other traits.

Lambing interval: The effect of interval between lambing seasons, 8-month vs $\geq$ 12-month, was evaluated for all traits in ewe records following a previous lambing. Records of ewes treated with hormones prior to spring breeding and ewes exposed in November for annual lambing were excluded, which left 3,341 ewe breeding season records.

The effect of lambing interval or its interaction with season was important only for fertility. The 8-month lambing depressed fertility by 11 percent when ewes were exposed to rams in August and by 5 percent when ewes were exposed to rams in December, but did not affect fertility when ewes were exposed to rams in April. For ewes exposed in August after lambing in May, postpartum and postlactational recovery occurred during the hot, stressful summer. Ewes exposed in December after lambing in September were under less stress because they produced smaller litters in September and had a cooler season for recovery.

The 8-month lambing interval decreased fertility (52 vs 65

pct) in F but not in half-F and other breeds. This suggests that the more prolific F ewes needed a longer time to recover fully from lambing and lactation.

Lambing season effects — accelerated lambing: Ewes subjected to hormone treatment were not included in this analysis.

Overall, fertility was 72 percent for May, 57 percent for January but only 17 percent for September lambing. Litter size averaged 1.93 for January, 1.83 for May and 1.49 for September lambing. Lamb survival to 1 day of age was lowest in January (86.5 pct), when litter size was largest, and highest in September (93.4 pct), when litter size was smallest. Preweaning survival for all lambs (including nursery-reared) was higher by approximately 3 and 5 percent, respectively, in September than in January or May, which again reflects the effects of smaller litter size and milder climate. Mean lamb weaning weights were about 1 lb less in May than in January or September, which probably reflects lower milk production and lamb creep intake over the hotter summer months. Total weight of lambs weaned per ewe exposed was slightly higher for May than for January lambing and about four times that for September lambing.

Annual vs accelerated lambing: A comparison of annual April lambing with accelerated January, May and September lambing was available for the purebred R and C1 cross ewes in 1978 and 1979. Average output per year per ewe exposed was considerably higher for annual April lambing than for the combined January, May and September lambings in lambs born (1.60 vs 1.24), lambs weaned (1.11 vs 0.84)and weight weaned (27.3 vs 22.3 lb).

Breed differences in season effects: Relative performance of breeds in various seasons of accelerated lambing is of particular interest. Since all breeds were not present in all seasons and years, partitioning of the data into two subsets (1976, 1977 vs 1978, 1979) permitted analysis of breed x season interactions over the maximum number of breeds. Differences between breeds remained consistent across lambing seasons in each data set for all traits except fertility. The mean fertility for each breed in each season is shown in Table 1.

Fertility did not differ between January and May for R or D but improved in May for T and more dramatically for F ewes. This breed effect is also evident in the higher fertility of the C1 crosses (FxR, FxD and $C1_1$) than for C2 crosses (FxS and FxT) in January, with little difference in May. Among the pure breeds, F had the highest fertility for September lambing. These results indicate a later onset of the breeding season for F and T compared with D and R ewes, and a later decline for F ewes. The F x D ewes also had a high fertility for September, but this estimate involved only 18 relatively old ewes (mean, 4.1 years). Overall, the crosses were similar to the pure breeds for fertility of September lambing, but they did respond somewhat better to hormone treatment.

In the 1978 and 1979 data set, fertility increased in F and F-crosses from January to May, but declined for R and did not change for D. The $C1_1$ and $C1_{2,3}$ ewes were highest in fertility for May lambing and $C1_1$ also were highest for September lambing.

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Table 1.—Breed differences in lambing season effects on mean ± fertility

Ewe breed	Season			
	January	May	September	September[1]
A. 1976 to 1977				
Finnsheep (F)	52.0 ± 3.2	83.7 ± 2.9	36.5 ± 4.4	27.0 ± 6.2
Rambouillet (R)	71.7 ± 2.1	70.6 ± 2.4	32.9 ± 3.1	16.4 ± 4.2
Dorset (D)	71.1 ± 2.3	73.3 ± 2.7	29.1 ± 3.4	10.4 ± 4.7
Targhee (T)	56.7 ± 3.7	67.3 ± 3.7	11.8 ± 5.0	9.7 ± 10.1
F x R	72.5 ± 4.4	88.1 ± 5.5	29.6 ± 6.0	3.3 ± 8.2
F x D	78.8 ± 5.3	91.7 ± 7.7	51.1 ± 7.4	42.5 ± 9.8
½F¼R¼D($C1_1$)[2]	78.1 ± 5.2	94.3 ± 2.7	31.9 ± 4.6	9.1 ± 6.3
FxSuffolk(S) or SxF	60.6 ± 5.6	96.6 ± 6.1	49.9 ± 7.7	12.1 ± 14.6
FxT or TxF	62.4 ± 3.3	87.2 ± 2.8	59.0 ± 4.4	13.2 ± 12.0
B. 1978 to 1979				
Finnsheep (F)	39.2 ± 2.5	76.4 ± 2.5	21.7 ± 3.3	19.6 ± 3.5
Rambouillet (R)	51.5 ± 2.5	34.7 ± 2.8	4.0 ± 2.6	.1 ± 2.9
Dorset (D)	60.6 ± 2.3	60.5 ± 2.2	24.2 ± 2.6	19.5 ± 2.9
½F¼R¼D($C1_1$)[2]	60.2 ± 3.1	85.9 ± 3.9	33.4 ± 4.5	25.8 ± 5.4
Composite 1 ($C1_{2,3}$)[3]	62.1 ± 3.4	87.3 ± 2.7	17.0 ± 3.3	12.5 ± 3.6

[1]Excluding ewes treated with hormone in 1976, 1977 and 1978.
[2]First generation of Composite 1 produced by mating F•R males to F•D females or vice versa.
[3]$C1_2$ produced by mating $C1_1$ males to $C1_1$ females; $C1_3$ produced by mating $C1_2$ males to $C1_2$ females.

Lamb Production and Its Components in Pure Breeds and Composite Lines. II. Breed Effects and Heterosis

Larry D. Young, Neal M. Fogarty and Gordon E. Dickerson[1]

Introduction

Crossbreeding has been used to combine the desirable traits of two or more breeds and to utilize heterosis in order to increase production. Another approach for using both complementary breed differences and crossbreeding heterosis to improve efficiency of market lamb production is development of composite populations from a crossbred foundation. Breed composition of composite strains can be chosen to achieve a balance of genetic characteristics best suited to a given production-marketing system. A composite strain also might be expected to excel the mean performance of the parent breeds because of heterosis retained in progeny from matings of crossbred parents.

This paper presents results of a study conducted to compare components of ewe performance for Dorset, Finnsheep, Rambouillet, Suffolk and Targhee purebreds and the early generations of two half-Finnsheep composite populations as potential maternal stocks in market lamb production.

Procedure

The data are from ewes mated to lamb in years 1976 through 1979. The data included purebred Dorset (D), Finnsheep (F), Rambouillet (R), Suffolk (S) and Targhee (T) and various crosses involved in the development of two composite lines (C1 = 1/2F,1/4R,1/4D and C2 = 1/2F,1/4S,1/4T). A total of 4,219 ewes having a total of 10,959 ewe breeding season records were included in the analysis.

Most ewes were exposed to lamb at 8-month intervals in January, May and September. In 1978 and 1979, some groups were exposed at 12-month intervals to lamb only in April. About one-half of the ewes of each breed group mated in April (September lambing) of 1976, 1977 and 1978 were treated with hormones to induce estrous activity. More details on management were presented in the preceding paper.

Seven components of total lamb production were defined for each ewe exposed: fertility (did or did not give birth to at least one lamb), litter size born, survival to 1 day of age of all lambs born, lambs weaned by the ewe of lambs born alive, lambs weaned by the ewe and in the nursery of lambs born alive, mean adjusted 42-day weight of lambs weaned on each ewe and mean adjusted 42-day weight of all suckled and nursery-reared lambs weaned from each ewe.

There was considerable variation in ewe performance between seasons and years and also from age of ewe, hormone treatment and lambing interval. To account for these effects, as well as differences in variation within seasons, the ewe traits were adjusted to an equivalent of a 3-year-old ewe and 12-month lambing interval and then standardized across all years and seasons. Hence, absolute values for performance of individual ewe breeds are useful mainly to allow comparisons among breed types using all of the data.

Heterosis for each cross was calculated as the deviation of the crossbred mean from the mean of the parental breeds (weighted by their contribution to the crossbred) and expressed as a percentage of the parental mean.

Results

C1 crosses: Means for the generations of C1 crosses and their paternal breeds and the corresponding estimates of heterosis are shown in Table 1. All crosses were superior to pure breeds in fertility, and F and D were higher than R. Heterosis in fertility was positive and highly significant for all generations of the crosses with little indication of decline from F_x (first 2-way crosses) to $C1_1$ (first 4-way crosses) and $C1_2$ (second generation of 4-way crosses) generation ewes. Litter size was 2.55 for F, about 1 lamb less for R and D, and just over 2.0 for all crosses. Heterosis was slight for litter size and was less in $C1_2$ than in the F_x or $C1_1$ generations. Despite their larger litters, lamb survival to 1 day of age was as high for the crosses as for R and D, and noticeably higher than for F; this amounted to about 5 and 4 percent heterosis for the $C1_1$ and $C1_2$ generations, respectively. Heterosis ranged from 11 to 16 percent for survival of lambs weaned on the ewe and 9 to 11 percent for survival of suckled and nursery-reared lambs, even though litters from crossbred ewes were slightly larger. Mean lamb weaning weight was 3 kg less for F than for R and D. Heterosis was negligible for mean lamb weaning weight. Crossbred ewes suckled from 0.2 to 0.4 more lambs than the mean for purebred ewes, which may have countered expression of any heterosis for growth to weaning in their crossbred lambs. The combined effect of heterosis in F_x to $C1_2$ generations for fertility and lamb survival amounted to 36 to 27 percent for number of lambs weaned and 30 to 29 percent for weight of lambs weaned per ewe exposed.

C2 crosses: Means for the C2 crosses and their parental breeds and the corresponding estimates of heterosis are shown in Table 2. Among the purebreds, fertility was highest for F and lowest for T. Heterosis in fertility ranged from 21 to 27 percent, and there was no indication of decline in heterosis from first cross to $C2_2$ generation ewes. Litter size of F was about one lamb above S and T ewes, and crosses were intermediate at just over 2.0 lambs. Heterosis was important in F_x (first 2-way crosses) ewes (3.6 pct) but declined in the $C2_1$ (first 4-way crosses) and $C2_2$ (second generation of 4-way crosses) crosses. Again, lamb survival at birth for crossbred ewes exceeded the parental breed mean, especially for the $C2_1$ and $C2_2$ generation ewes. Survival of lambs on the ewe was much higher for C2 crosses than for the pure breeds; lambs from F ewes were very low for survival, partly because a larger proportion of F lambs were reared in the nursery. The S ewes weaned 10 percent fewer lambs than T ewes even though they differed little in litter size born alive. Hence, heterosis for survival of lambs on the ewe was 14 percent for first crosses but 25 percent for $C2_1$ and 20 percent for $C2_2$. Because inclusion of nursery-reared lambs increased survival for lambs from F ewes more than for other breeds, heterosis for total preweaning survival (suckled and nursery-reared lambs) was reduced to 10, 19 and 16 percent for first-cross, $C2_1$ and $C2_2$, respectively. Mean lamb weaning weight was about 5 kg less for F than S ewes and was intermediate for T ewes. There was little variation among crosses and heterosis for lamb weaning weight was 3 to 4 percent for the F_x and $C2_1$ ewes. Again, the larger litters reared by the crossbred ewes would have reduced expression of heterosis for preweaning growth rate of crossbred lambs. Total heterosis in output per ewe exposed in the F_x to $C2_2$ generations was 41 to 38 percent for number weaned and 44 to 31 percent for weight of lambs weaned.

General: Tables 1 and 2 are from the same analysis, and hence breeds can be compared between tables. This will be left to the reader.

Expression of litter size and lamb weaning weight on a per ewe exposed basis greatly magnifies the differences between crosses and purebreds because of the combined effects of the large differences in fertility and in lamb survival. Heterosis in fertility and in lamb survival were higher in the present study

than in most earlier studies, probably because of the low mean fertility and lamb survival under the accelerated lambing program of the present study (April, August and December breeding).

The level of heterosis for C2 crosses tended to be slightly higher than for C1 crosses for most traits. However, this difference arose solely from the lower purebred mean of breeds contributing to C2, since actual performance levels of C1 and C2 were very similar.

Results of this study indicate that it may be feasible to develop composite dam lines to utilize breed combinations and heterosis for commercial lamb production without the expense of maintaining purebred lines for continual production of first-cross ewes. However, a later analysis of more extensive intra-year comparisons of later generations of C1 and C2 and purebreds will provide better evidence.

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Table 1.—Means[1] (± SE) for components of ewe production by Composite 1 and parental breeds, and heterosis levels by generations of crossing[1]

				Lamb survival (pct)				
					Preweaning		Weaning wt/lamb[3] (lb)	
Ewe breed[2]	Number of sires/ewes/ records	Fertility pct	Lambs born No.[3]	To 1 day	On ewe	Total	On ewe	Total
Finnsheep (F)	89/599/1,431	70.0	2.55	86.0	57.8	67.8	22.7	21.6
Rambouillet (R)	72/628/1,960	62.7	1.58	92.5	76.5	79.8	28.9	28.4
Dorset (D)	66/599/1,768	71.5	1.54	91.8	85.1	86.2	28.4	28.2
FxR $\overline{FX}$	10/ 79/ 212	75.1	2.05	88.6	78.2	83.5	26.5	25.8
FxD	9/ 53/ 133	85.4	2.17	94.6	75.7	80.6	24.9	24.5
½F¼R¼D ($C1_1$)	12/401/1,247	82.2	2.13	93.4	79.6	83.9	25.8	25.3
$C1_2$	27/355/ 711	80.0	2.01	92.5	80.2	83.8	25.8	25.6
Range of S.E.[4]		1.0-4.0	.02-.06	.8-2.4	1.2-3.5	1.1-3.4	.22-.66	.22-.66
Parental mean ($\overline{P}$)[5]		68.6	2.06	89.1	69.3	75.4	25.6	24.9
Heterosis, pct								
100 ($\overline{FX}$ − $\overline{P}$)/$\overline{P}$[6]		[8]17.1	2.4	2.9	[8]11.0	[7]8.9	−.2	.1
100 ($C1_1$ − $\overline{P}$)/$\overline{P}$		[8]19.9	[7]3.6	[7]4.9	[8]14.9	[8]11.3	.7	1.5
100 ($C1_2$ − $\overline{P}$)/$\overline{P}$		[8]16.7	−2.2	[7]3.9	[8]15.7	[8]11.22	.9	2.6

[1]Adjusted for age of ewe and for year-season. See text.
[2]$C1_1$ ewes were reciprocal crosses of F•R x F•D. $C1_2$ ewes were from *inter se* matings of $C1_1$.
[3]Per ewe lambing.
[4]S.E. is the standard error of the mean.
[5]$\overline{P}$ = ½F + ¼R + ¼D.
[6]Assuming that FR = RF in ewe performance.
[7](P<.05) after adjusting the within-breed S.E. shown to a sire/breed basis.
[8](P<.01) after adjusting the within-breed S.E. shown to a sire/breed basis.

Table 2.—Means[1] (± SE) for components of ewe production by Composite 2 and parental breeds, and heterosis levels by generations of crossing

Ewe breed[2]	Number of sires/ewes/records	Fertility pct	Lambs born No.[3]	Lamb survival (pct) To 1 day	Lamb survival (pct) Preweaning On ewe	Lamb survival (pct) Preweaning Total	Weaning wt/lamb[3] (lb) On ewe	Weaning wt/lamb[3] (lb) Total
Finnsheep (F)	89/599/1,431	70.0	2.55	86.0	57.8	67.8	22.7	21.6
Suffolk (S)	50/103/ 164	62.4	1.62	90.8	65.5	69.7	33.3	32.0
Targhee (T)	26/219/ 591	51.7	1.51	91.1	75.9	79.0	28.0	27.8
½F½S$_{\overline{FX}}$	11/ 57/ 173	77.4	2.21	85.4	69.0	74.3	27.6	27.1
½F½T	10/212/ 680	76.7	2.06	94.2	77.2	82.5	27.3	26.7
½F¼S¼T ($C2_1$)	17/373/ 560	80.7	2.10	91.7	80.5	84.6	27.1	26.7
$C2_2$	15/104/ 135	79.2	2.04	95.2	76.8	82.4	26.5	26.0
Range of S.E.[4]		1.2-4.0	.02-.06	.9-2.4	1.3-3.5	1.3-3.3	.22-.66	.22-.66
Parental mean ($\overline{P}$)[5]		63.5	2.06	88.4	64.3	71.1	26.7	25.8
Heterosis, pct								
100 ($\overline{FX}$ − $\overline{P}$)/$\overline{P}$[6]		[8]21.4	[7] 3.6	1.5	[8]13.7	[8]10.3	3.0	[7]4.2
100 ($C2_1$ − $\overline{P}$)/$\overline{P}$		[8]27.0	1.9	3.6	[8]25.2	[8]19.0	1.4	[7]3.3
100 ($C2_2$ − $\overline{P}$)/$\overline{P}$		[8]24.7	−.8	[7]7.6	[8]19.5	[8]15.9	−.9	.6

[1]Adjusted for age of ewe and for year-season. See text.
[2]$C2_1$ ewes were reciprocal crosses of F•S x F•T. $C2_2$ ewes were from *inter se* matings of $C2_1$.
[3]Per ewe lambing.
[4]S.E. is the standard error of the mean.
[5]$\overline{P}$ = ½F + ¼S + ¼T.
[6]Assuming that FS = SF in ewe performance.
[7](P<.05) after adjusting the within-breed S.E. shown to a sire/breed basis.
[8](P<.01) after adjusting the within-breed S.E. shown to a sire/breed basis.

Lamb Production and Its Components in Pure Breeds and Composite Lines III. Genetic Parameters

Larry D. Young, Neal M. Fogarty and Gordon E. Dickerson[1]

Introduction

The proportion of total costs accounted for by replacement and maintenance of the breeding female is much higher for sheep and beef cattle than for the other meat-producing species, mainly because of their relatively low reproductive rate. For sheep, there is a much greater potential for increase in both biological and economic efficiency through genetic improvement in reproductive rate than in growth rate or body composition, at least when wool is not important. Reproductive rate, defined as number or weight of lambs weaned per ewe exposed, is dependent on various components; namely, fertility, litter size, neonatal and postnatal lamb survival and lamb growth. The development of efficient selection programs depends on a knowledge of heritability and variation as well as phenotypic and genetic correlations between the various component traits. This paper reports estimates of repeatabilities, heritabilities and phenotypic and genetic correlations for measures of ewe productivity under annual and accelerated lambing management regimens and their use in formulating optimum selection programs.

Procedure

The data were collected on ewes mated to lamb from 1976 to 1979. Ewes were either purebred Dorset (D), Finnsheep (F), Rambouillet (R), Suffolk (S) and Targhee (T) or various crosses in the development of two composite dam lines (C1 = 1/2F, 1/4D,1/4R and C2 = 1/2F,1/4S,1/4T). Lambing occurred in January, May and September in all years, with most ewes exposed to lamb at 8-month intervals. In 1978 and 1979 some groups were exposed annually to lamb in April. Management details were presented in the first two articles of this series.

For each ewe exposed to lamb in a given year-season, the number of lambs weaned and weight of lamb weaned were defined. These two composite traits are determined by fertility, litter size, lamb survival to 1 day of age (neonatal survival), survival from 1 day of age to weaning (postnatal survival) and mean lamb weaning weight (adjusted to 42 days of age and a ram lamb equivalent). Records of nursery-reared lambs were included. Performance was standardized in order to compare ewes with different sequences of breeding seasons, different lambing/breeding intervals, and to account for vastly different levels of performance in the various lambing seasons, especially for fertility. The traits also were adjusted to a three-year-old ewe equivalent for each ewe.

Nested analyses of variance were used to obtain half-sib estimates of heritability for individual records of standardized traits, and for the mean of repeated records for each ewe. Repeatability was estimated by intraclass correlation. Genetic and phenotypic correlations also were obtained between mean record traits (average value of a trait over all parities) by nested analyses of variance.

Results

Repeatability of ewe performance. Estimates of repeatability for ewe performance traits are presented in Table 1. Repeatability estimates refer to the expression of the same trait at different times in the life of the same individual. Repeatability estimates predict the fraction of differences between single records of individuals that are likely to occur in future records of the same individuals. In this study, estimates of repeatability of ewe performance were low but within the range found in the literature. The pooled regression estimates of repeatability are less subject to bias and were higher for litter size (.16), weaning weight (.10), fertility (.09), number of lambs weaned per ewe exposed (.12) and weight of lambs weaned per ewe exposed (.12) than lamb survival (.03 and .02).

Heritability of ewe performance. Heritability estimates of both individual and lifetime mean ewe records are also presented in Table 1. Heritability estimates indicate how much of the total variation in performance between ewes is due to genetic differences. Heritability estimates for individual records are relatively low and indicate that most of the differences among ewes are due to environmental effects. The considerably higher heritability for mean ewe records was expected, especially for lamb survival, and illustrates the desirability of using repeated records on each ewe to obtain more accurate estimates of breeding value for reproductive traits.

Correlations among component traits. Estimates of phenotypic and genetic correlations among mean ewe traits are presented in Table 2. Correlations of number weaned and weight weaned per ewe exposed with the other traits are partially due to the fact that these two traits result from multiplication among their component traits.

Phenotypic correlations of mean fertility with litter size, neonatal survival, postnatal survival and mean weaning weight were near zero but higher ($r_p = .6$) with number and weight of lamb weaned. Litter size was negatively correlated with neonatal and postnatal survival and mean lamb weight, but positively correlated with number and weight of lamb weaned per ewe exposed. Both number and weight of lamb weaned were moderately correlated with neonatal ($r_p = .3$) and postnatal ($r_p = .6$) survival.

Genetic correlations had relatively high standard errors and their magnitude fluctuated widely because of the low genetic variance for some traits. Litter size was negatively correlated, genetically, with fertility, neonatal survival, postnatal survival and mean weaning weight and thus was a poor genetic predictor ($r = 0$) of number or weight of lambs weaned per ewe exposed. Genetic correlations of weight of lamb weaned with fertility, lamb survival and mean weaning weight were moderate to high (.4 to .9) and positive. Similarly, the genetic correlation of number weaned with fertility and lamb survival were moderate to high and positive (.3 to 1.0).

Relative importance of component traits. Weight of lamb weaned per ewe exposed is a composite trait, with multiplicative contributions from five components, namely: fertility, litter size, neonatal survival, postnatal survival and weaning weight. Similarly, number of lambs weaned is determined by the first four component traits. Path coefficient methodology was used to determine the standard partial regression coefficients for the composite traits on the component traits for both genetic and environmental effects. The coefficients are shown in Table 3 and measure the direct change of the composite trait (in standard deviation units) per standard unit change in the component traits, while holding all other traits constant. Hence, any indirect association through other component traits is omitted. These partial regression coefficients are estimates of the relative importance of each component trait in predicting lamb output per ewe exposed. The larger the coefficient, the more important it is in determining the composite trait.

The generally larger and more variable values of the standard partial regressions using the genetic rather than the phenotypic correlations reflect the lower precision associated with the estimates of genetic correlations. However, the relative values of the coefficients for each of the component traits are

similar for genetic and phenotypic contributions. Note the important contributions of fertility and preweaning survival to both weight and number of lambs weaned per ewe exposed. Direct effects of fertility accounted for 37 percent of the phenotypic variance in both composite traits, and preweaning survival accounted for 36 and 39 percent of the phenotypic variance in weight and number of lambs weaned, respectively. Litter size only accounted for 15 and 8 percent of the phenotypic variance in weight and number of lambs weaned, respectively. Such important contributions of fertility and lamb survival are undoubtedly related to the low mean levels of fertility and survival in the data and would probably be less important for optimum seasonal annual lambing if the September lambing were omitted, or under conditions of higher lamb survival. The corresponding partial regressions based upon the phenotypic correlations are clearly more reliable than those based on genetic correlations and, therefore, more suitable for estimating relative importance of the component traits in predicting output per ewe exposed.

These results highlight the importance of considering postnatal survival and fertility, as well as the other components, in selection programs aimed at increasing reproduction. Past recommendations have emphasized selection for litter size in preference to composite traits or an index, because heritability estimates for litter size have tended to be higher. Little permanent benefit has been predicted from culling dry ewes. Often little variation is expressed for fertility and lamb survival because performance is near the upper limit (100 pct) or can be improved by non-genetic means. However, under accelerated lambing regimens, where at least some breeding seasons are in periods of reduced estrous activity, more genetic variation for fertility can be expressed. In this study, fertility was low because breeding was scheduled early or late in the normal breeding season or in the anestrous season under an accelerated lambing program. Hence, more variability was expressed for fertility, and this component was an important source of genetic and phenotypic variation in overall reproductive rate. Similarly, lamb survival was low throughout the study, and the resulting increased variability contributed markedly to the variation in overall reproductive rate.

These results further point out the possible importance of genotype x environment interactions, not only between different geographical areas, but between different management situations. Optimum selection indexes may have quite different weightings for an annual spring lambing flock than for a flock under an accelerated lambing system. It is also important that flocks be monitored regularly so that changes in the environment which bring about changes in importance of index components can be taken into account.

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Table 1.—Repeatability[1] and paternal half-sib heritability[2] estimates (± SE)

	Repeatability		Heritability	
	Intraclass correlation	Pooled regression	Individual record	Mean record
Component traits				
Fertility	.06 ± .01	.09 ± .02	.06 ± .02	.09 ± .05
Litter size	.08 ± .02	.16 ± .03	.11 ± .04	.16 ± .06
Neonatal survival	.15 ± .02	.03 ± .02	.02 ± .04	.10 ± .06
Postnatal survival	.11 ± .02	.02 ± .02	.07 ± .04	.15 ± .06
Mean weaning weight	.13 ± .03	.10 ± .03	.10 ± .05	.13 ± .07
Composite traits[3]				
Lambs weaned	.05 ± .01	.12 ± .02	.03 ± .02	.06 ± .05
Weight weaned	.05 ± .01	.12 ± .02	.06 ± .02	.15 ± .05

[1]Predicts the fraction of differences between single records of individuals that are likely to occur in future records of the same individuals.
[2]The proportion of variation among observed performance that is due to variation in genetics.
[3]Per ewe exposed.

Table 2.—Phenotypic[1] (above diagonal) and genetic[2] (below diagonal) correlations (± SE) between mean record traits

	Fertility	Litter size	Neonatal survival	Postnatal survival	Mean weight	Lambs weaned[3]	Weight weaned[3]
Fertility		.03 ± .02	.03 ± .02	−.02 ± .02	−.01 ± .02	.61 ± .01	.61 ± .01
Litter size	−.34 ± .28		−.15 ± .02	−.20 ± .02	−.38 ± .02	.26 ± .02	.13 ± .02
Neonatal survival	−.22 ± .35	−.30 ± .32		.08 ± .02	.06 ± .02	.34 ± .02	.35 ± .02
Postnatal survival	−.09 ± .30	−.32 ± .28	.78 ± .52		.16 ± .02	.55 ± .01	.58 ± .01
Mean weight	.18 ± .33	−.39 ± .24	1.42 ± 2.04	−.26 ± .82		−.14 ± .02	.23 ± .02
Lambs weaned[3]	.30 ± .44	.04 ± .40	.68 ± .41	1.60 ± 1.30	0		.94 ± .00
Weight weaned[3]	.58 ± .21	−.02 ± .27	.49 ± .28	.91 ± .17	.41 ± .44	1.05 ± .11	

[1]Measures the degree of interdependence of two traits. Zero values indicate the traits are independent. Values of 1.00 indicate the traits are completely dependent.
[2]The degree with which the same genes affect both traits. Zero values indicate the traits are under different genetic control. Values of 1.00 indicate the traits are controlled by the same genes.
[3]Per ewe exposed.

Table 3.—Standard partial regression coefficients[1] for weight and number of lambs weaned (per ewe exposed) on the component traits

Component trait	Weight weaned		Lambs weaned	
	Genetic[2]	Phenotypic[3]	Genetic[2]	Phenotypic[3]
Fertility	1.029	.606	.588	.607
Litter size	.668	.384	.792	.287
Neonatal survival	.596	.325	−1.144	.325
Preweaning survival	.712	.597	2.799	.621
Mean weight	−.172	.269	—	—

[1]Measures the direct change in the composite trait (in standard deviation units) per standard deviation unit change in the component traits while holding all other traits constant.
[2]Derived from genetic correlations among the traits.
[3]Derived from phenotypic correlations among the traits.

Importation of Booroola Merinos from New Zealand

Larry D. Young[1]

Booroola Merinos at MARC

On September 17, 1983, 21 Coopworth ewes impregnated with Booroola Merino embryos and 5 Booroola Merino rams arrived at MARC after a quarantine period of about 30 days in Hawaii and a departure from Auckland, New Zealand, on August 11, 1983. The importation was made feasible through a Memorandum of Understanding between the U.S. Department of Agriculture, Agricultural Research Service, and the New Zealand Ministry of Agriculture and Fisheries.

Coopworth ewes were used as surrogate mothers for the Booroola Merino embryos because there were an insufficient number of Booroola Merino ewes available for export from New Zealand. However, five Booroola Merino rams, one year old or older, were made available.

Booroola Merinos are a strain of Australian Merino sheep and are of interest because of their large litter size. Although the Merino is famous for its wool production, lamb crops in excess of 120 percent are rare for Merinos in any country. The Booroola strain of Merino, however, possesses a gene that has a major effect on ovulation rate and consequently on litter size. It is quite unusual to find a single gene that has such a major effect on an economically important trait in a livestock species. The litter size of the Booroola Merino with two copies of the gene is comparable to that of Finnsheep (about 2.7 lambs). Current information suggests that the Finnsheep does not possess this gene.

Eighteen of the 21 Coopworth ewes were actually pregnant. They gave birth to 17 ram lambs and 12 ewe lambs between November 8 and November 17, 1983. Two ewe lambs and one ram lamb died at birth or shortly thereafter. After the lambs were weaned, the Coopworth ewes were transferred to Oregon State University for use in their research program.

At MARC, the Booroolas will be compared to the Finnsheep for growth, carcass merit, wool production and reproduction. Efforts will be made to back-cross the Booroola prolificacy gene and Finnsheep prolificacy gene into a third population of sheep. Efforts will be made to determine how the Booroola gene increases ovulation rate.

History of Booroola Merino

In 1954, the Commonwealth Scientific Investigations and Research Organization (CSIRO) of Australia established two Merino groups of the Peppin strain, selected for or against twinning. Contrary to expectations, progress of about 1 percent a year was made in lambs born per ewe exposed. Publicity was given to these findings in the Australian press.

After reading about the CSIRO experiments, two brothers named Seears offered CSIRO a ram lamb which had been born in a litter of five. CSIRO purchased 12 yearling ewes born as triplets or quadruplets and a two-year-old ewe which had produced triplets her first lambing. The next year a quintuplet ram was acquired and the following year a sextuplet ewe. Examination of the Seears brothers' flock showed that a special "multiple-birth" flock had a lambing percentage around 170 to 180 percent. This multiple-birth flock was sold in 1965 after the sudden deaths of the brothers in 1959 and 1960. CSIRO took 91 ewes, aged 2 to 6 years, which had been born as multiples.

The new strain was named Booroola after the name of the Seears' property. The flock is of the "Egelabra" strain. The multiple-birth flock was begun with a ewe producing triplets in the main flock. Thereafter, all ewes seen with multiples were transferred to the special flock. One of the most surprising features was that selection was only on the ewe side; all rams were purchased with no reference to the dam's lambing history.

CSIRO continued selection on both sexes and now the Booroola's average litter size at birth is about 2.7 lambs. Examination of the pedigree records showed that the greater fecundity of the Booroolas could be attributed to the action of a single major gene on ovulation rate. In the Merino breed, the addition of a single copy of the gene increases ovulation rate from about 1 egg to about 2 eggs. Ewes having two copies of the gene ovulate even more eggs (3 or more). Embryo mortality increases as ovulation rate increases, thus litter size born increases less than ovulation rate.

By selecting ewes with repeated records of multiple births, the Seears brothers were picking out individuals carrying the major gene. The source of the major gene may be from either the Cape (from Cape of Good Hope) or Bengal (from Calcutta) sheep that were imported into New South Wales early in the settlement of Australia. Early records indicated these sheep were prolific.

Despite intensive studies, the mechanism by which the Booroola gene produces an increase in ovulation rate is not known. The gene does not appear to have any effect on other performance traits. The absence of effects on other performance traits gives the gene great potential value since it should be possible to introduce it into any other sheep breed, by a system of repeated backcrossing, without affecting characteristics other than litter size. However, there is curently no way of recognizing rams that carry the gene without progeny testing them.

The Booroola gene is being exported to other countries, and it will be interesting to see the effect of the gene in breeds that are more prolific than the standard Merino. For many situations, the levels of fecundity resulting from the Booroola gene may be too great for practical utility. A better understanding of how the gene works may allow development of methods of modifying its action to produce more desirable levels of fecundity.

In the distant future, identification of the location of the gene might make it useful for genetic engineering purposes in that it could be transferred to other species.

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Efficient Production of Protein. I. Component Traits of Growth

Kreg A. Leymaster and Tom G. Jenkins[1]

Introduction

Rate of growth and composition of the body generally are recognized as traits of economic importance to the sheep industry. Improvement of these traits depends on applying effective programs of selection, that is, identifying replacement animals of superior genetic merit. This rather complex process is simplified by an understanding of how traits interact with one another. Such an understanding permits a biological model of developmental growth to be constructed and to serve as the foundation upon which decisions of selection can be based.

Although rate of growth has been studied widely, information to construct a biological model of developmental growth is incomplete due to the scarcity of published data on composition of sheep. An experiment, therefore, was conducted to determine interrelationships among component traits that contribute to developmental growth.

Procedure

Data were collected on purebred Suffolk ram lambs produced during 1980 and 1981. Rams were left intact, weaned at an average age of 50 days and offered a pelleted diet *ad libitum* for the remainder of the study. Sixty-eight rams were slaughtered at 70 lb and 58 rams at 160 lb. The skinned head, heart, lungs, liver, kidneys, spleen, testes and empty gastrointestinal tract were pooled together as offal for each ram. Chemical estimates of fat, protein and ash were determined separately on carcass and offal components of each ram. The traits of interest were composition and rates of deposition. Compositional traits were calculated as the proportions (relative to liveweight) of carcass fat, protein and ash and offal fat, protein and ash. These compositional traits were determined at 70 and 160 lb and used with rate of growth to estimate rates of deposition (lb per day). Rates of deposition were, therefore, estimated for fat, protein and ash in the carcass as well as in the offal.

Results

The means of compositional traits are presented in Table 1 for rams slaughtered at 70 lb and for rams slaughtered at 160 lb. Several factors were identified that affected compositional traits. In general, results indicated that rams younger at 70 lb had more fat in the carcass and offal and had less protein and ash in the carcass and offal than rams older at 70 lb. Less consistent effects of age at slaughter on compositional traits were found for rams slaughtered at 160 lb. Effects of age of dam and type of birth-rearing status often interacted with age at slaughter to affect compositional traits at 70 and 160 lb. Compositional traits involving protein and ash generally were correlated to one another significantly and in a positive manner. For example, rams with high proportions of carcass protein also tended to have high proportions of offal ash.

With regard to compositional traits, several conclusions were made. Natural variation in rate of growth affected composition adversely, that is, rams that were youngest at slaughter tended to have less protein in the carcass than rams that were older at slaughter. Influences of the dam (age of dam and reproductive level) frequently affected compositional traits of progeny. Such influences likely were manifested by the amount of milk available to progeny.

Rates of deposition during growth from 70 to 160 lb were also analyzed. The average rate of growth (average daily gain) was 0.81 lb per day. The contributions of six component traits (average rates of deposition) to rate of gain are illustrated in Figure 1. Fat was deposited in the carcass approximately three times more rapidly than protein. A similar relationship was noted for offal. As detected for compositional traits, rates of deposition were affected by age at slaughter, age of dam and type of birth-rearing.

The net effects of depositional traits in determining compositional traits at 160 lb were partitioned into direct and indirect effects. Direct effects represent influences that are attributable to a single trait, whereas indirect effects are associated with influences shared in common with other traits being considered. The six depositional traits jointly accounted for 77, 49, 77, 90, 68 and 85 percent of the variation in carcass fat, protein and ash and offal fat, protein and ash, respectively. Results indicated the major effects that rates of deposition of carcass protein and offal protein exerted during developmental growth.

The percentages of variation in rate of growth explained by direct effects of depositional traits are illustrated in Figure 2. Depositional traits explained 80 percent of the variation in rate of growth. Significant effects of rates of deposition of offal protein, carcass protein and offal ash were detected. It is interesting to compare the average rates of deposition (Fig. 1) with the relative importance of depositional traits as they determine rate of growth (Fig. 2). Rate of deposition of carcass fat was approximately 14 times greater than rate of deposition of offal protein (Fig. 1). However, rate of deposition of carcass fat had an insignificant direct effect on rate of growth, whereas the direct effect of rate of deposition of offal protein was highly significant. It was hypothesized that rate of deposition of carcass fat may be an effect partially mediated by rate of deposition of offal protein.

Future research will continue to examine models of developmental growth. This effort will be expanded to include recording of feed consumption of individual rams as well as to pursue the major role that rate of deposition of offal protein apparently exerts during developmental growth.

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Table 1.—Means of compositional traits measured at 70 and at 160 lb[1]

	Carcass			Offal		
Weight	Fat	Protein	Ash	Fat	Protein	Ash
70 lb	5.5	7.4	2.2	1.6	2.3	.6
160 lb	14.5	7.3	2.4	3.7	1.8	.5

[1]Compositional traits are expressed as a percentage of liveweight.

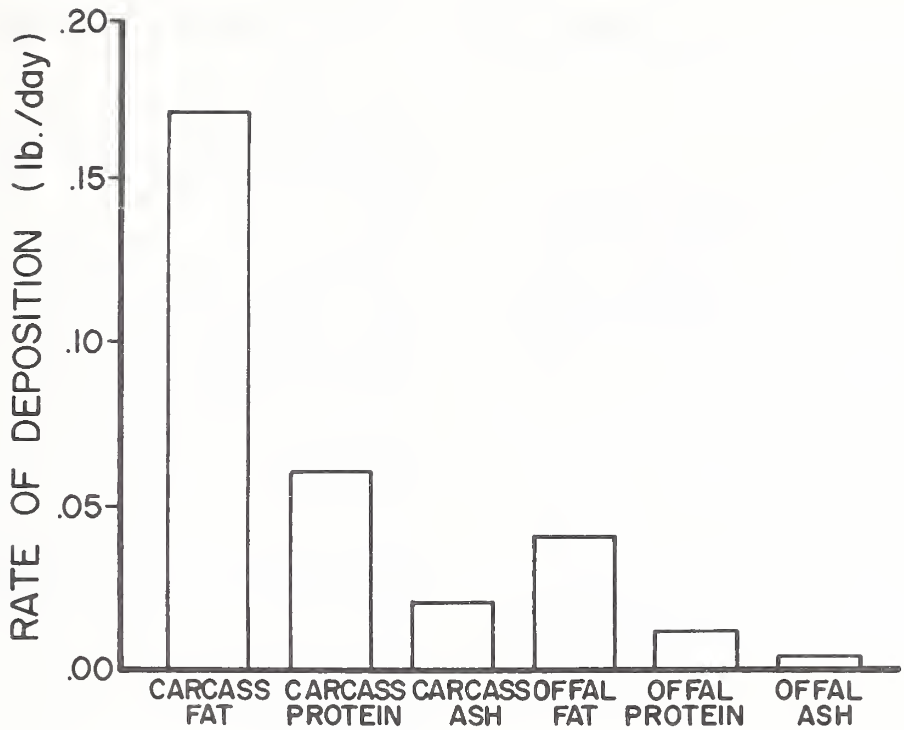

Figure 1—Average rates of deposition for component traits of rate growth.

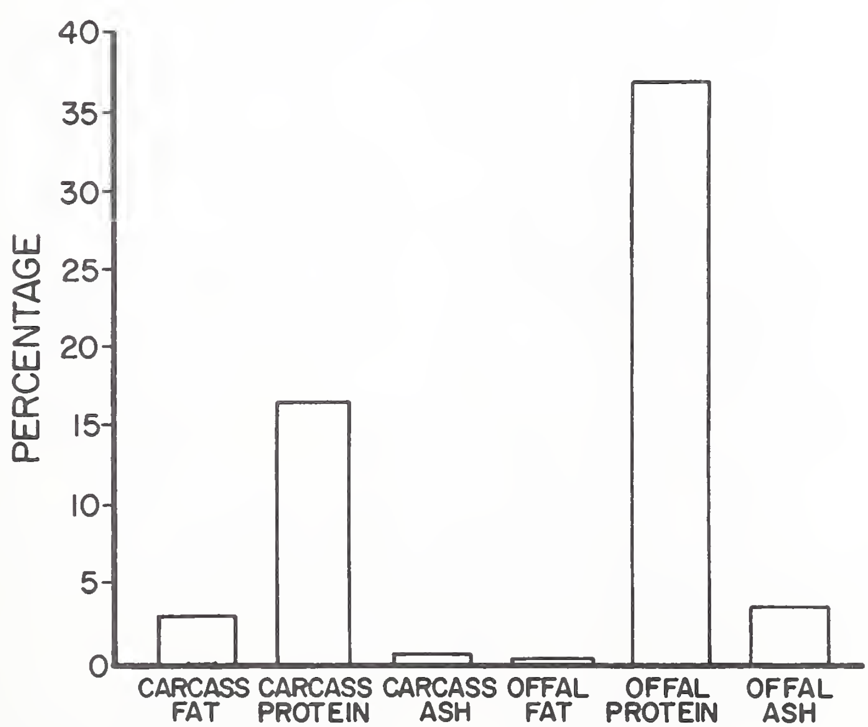

Figure 2—Percentages of variation in rate of growth explained by direct effects of depositional traits.

Efficient Production of Protein. II. Use of Ultrasonics to Predict Composition

Kreg A. Leymaster, Harry J. Mersmann and Tom G. Jenkins[1]

Introduction

The rate of future genetic improvement of efficient production of protein depends in part on methods to estimate accurately and precisely the composition of living animals. Of the many techniques that have been developed, ultrasonic instruments are among the most useful. Ultrasound is based on the reflection (echoes) of high frequency sound waves as the sound waves pass through tissues (fat, muscle and bone) that differ in density. This information is interpreted as distances between tissues; for example, depth of fat.

Ultrasound can be used to estimate carcass composition of live sheep. Such efforts have been attempted previously, but results generally were inconsistent and levels of precision were of rather limited usefulness. The application of ultrasound to sheep has been hindered by the existence of wool, soft fat and mobile skin in addition to standardized use of the last rib for measuring depth of fat.

The experimental objective was to evaluate the usefulness of ultrasound to augment routine traits as predictors of compositional traits at 160 lb and of rates of deposition during growth from 70 to 160 lb.

Procedure

Data were collected on 37 Suffolk rams that were slaughtered at 160 lb. Compositional traits and rates of deposition were determined as described in the preceding paper. One day prior to slaughter, rams were scanned ultrasonically and the information recorded on Polaroid[2] film. Wool was shorn from four locations: the sternum, posterior to the shoulder, the last rib and the tailhead. Mineral oil was applied to the shorn areas to ensure adequate contact between the skin and the ultrasonic equipment. Ultrasonic estimates of subcutaneous fat at the sternum, last rib and tailhead and of body wall thickness at the shoulder were determined from Polaroid pictures. Depth of fat and area of fat were recorded. Figure 1 illustrates the equipment being used.

Data were analyzed initially to determine how precisely routine traits could predict variation in composition and rates of deposition. Routine traits evaluated included age at slaughter, age of dam and type of birth-rearing. Effects of ultrasonic estimates were then added to the statistical models and their usefulness evaluated as the improved precision achieved beyond that provided by routine traits.

Results

From a predictive standpoint, traits that have a high degree of variation relative to their means tend to be more useful than traits with less variation. Of the four scan locations examined, measurements at the last rib and tailhead locations were more variable than measurements at the sternum and shoulder locations.

The value of ultrasonic linear measurements to augment routine traits as predictors of composition and rates of deposition is presented in Table 1. Addition of various ultrasonic estimates of depth of fat significantly increased the percentage of variation explained in carcass compositional traits. For example, routine traits accounted for 38.7 percent of the variation in carcass fat; this value increased to 65.8 percent by including the most informative ultrasonic estimates. However, ultrasonic estimates did not significantly improve prediction of offal compositional traits. The scan locations that consistently provided the most useful information were the last rib and the tailhead. In general, as ultrasonic estimates of depth of fat increased, carcass fat also increased, whereas carcass protein and ash tended to decrease. Estimates of fat area were also of predictive value, but generally less useful than estimates of depth of fat.

The percentages of variation explained for rates of deposition of carcass fat, protein and ash and offal protein were increased significantly by including ultrasonic estimates of depth of fat. Prediction of rates of deposition of offal fat and ash were not affected significantly. As noted for compositional traits, measurements determined at the last rib and tailhead locations were more useful for estimation of rates of deposition than information obtained at the sternum and shoulder locations. Similarly, estimates of certain fat areas were useful, although less informative than estimates of depth of fat.

The present research was more successful than previously reported efforts with a single exception. The predictive merit of measurements determined at the tailhead, a location heretofore untested, contributed to the favorable results. Additional research is warranted to validate these findings.

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[2]Trade names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement by the Department over other products not mentioned.

Table 1.—Value of ultrasonic linear estimates to predict composition and rates of deposition

	Composition					
	Carcass			Offal		
	Fat	Protein	Ash	Fat	Protein	Ash
Routine traits[1]						
R^2 value (pct)[2]	38.7	48.5	62.3	56.4	29.3	57.2
Routine traits plus ultrasonic estimates						
R^2 value (pct)	65.8	74.6	78.3	62.5	43.5	69.4
	Rates of Deposition					
	Carcass			Offal		
	Fat	Protein	Ash	Fat	Protein	Ash
Routine traits						
R^2 value (pct)[2]	55.3	71.7	32.3	54.7	77.0	66.4
Routine traits plus ultrasonic estimates						
R^2 value (pct)[2]	69.3	78.0	62.6	63.7	83.6	82.0

[1]Routine traits used to predict composition and rates of deposition included age at slaughter, age of dam and type of birth-rearing.
[2]The R^2 statistic represents the percentage of variation in composition or rate of deposition that is explained by the predictors. (Higher percentage indicates greater potential predictive value.)

Figure 1—Ultrasonic equipment being used on a Suffolk ram.

Proportion of Carcass from Hot-Boned Ram and Wether Lambs Suitable for Restructured Chunked and Formed Roasts

Ray A. Field, H. Russell Cross and Steve C. Seideman[1]

Introduction

Many different kinds of restructured meat products can be made. In the past, flaked, ground and emulsified restructured meat products have been popular because they have utilized meat trimmings and meat pieces which are small or irregular in size. Meat used has often been high in fat or connective tissue, or it has come from tough, low-grade animals. Retructured meat products have been referred to as intermediate meat products because they are intermediate in price between ground meat and intact muscle steaks. Chunked and formed meat, in contrast to thinly flaked, finely ground or emulsified restructured meat products, has the advantage of producing a texture most like intact muscle steak. The major disadvantage of chunked and formed products which can be produced from intermediate or large flake sizes, from cubed meat, from coarsely ground meat or from intact muscles, is that the meat used must be tender and low in fat and connective tissue.

Although numerous publications on fat, lean and bone content of the lamb carcass are available, very little information is available on the amount of lean in a lamb carcass which is suitable for chunked and formed steaks and roasts. In addition, information is lacking on yield of mechanically separated lamb (MSL) and other lean in a lamb carcass which is not suitable for chunked and formed roasts.

It was the objective of this research to obtain information on yields of lean and MSL from choice and prime lamb carcasses. Information on the yields of other lean, fat trim and some by-products obtained from ram and wether lambs is also presented.

Procedure

Fifty ram lambs and 49 wether lambs were slaughtered at 5-6 months of age (approx. 101 lb liveweight) in two groups consisting of 25 ram and 25 wether lambs each. Lambs were half-Finn, quarter-Dorset and quarter-Rambouillet. By-product weights were collected on the kill floor.

Lamb carcasses were hot-boned 2 h post-mortem. The fell membrane and subcutaneous fat were first stripped from the hot carcasses. Subcutaneous fat, kidney and pelvic fat, and all other intermuscular fat deposits over 0.5 in thickness were included as fat trim. Major muscles (leg, loin, rib and shoulder) were then stripped from the hot carcass as it hung on the rail. The skeleton included intact muscles from the hindshanks, foreshanks, neck and all muscles next to bones which were considered uneconomical to remove by hand. Lean, fat and skeletons were weighed separately from each lamb immediately after boning. Lean from the legs, loin, rib, shoulder and skeleton was placed in polyvinyl chloride bags, boxed and stored in a 36°F cooler until hot-boning of all carcasses was completed. The boxes were then transferred to a freezer until meat was crust frozen prior to being transported from MARC to the University of Wyoming Meat Laboratory. When the meat and bones arrived approximately 24 h after slaughter, the internal temperature of the meat was 39°F. Meat from the leg, loin, rib and shoulder of all lambs was ground through a 1.5 in kidney plate and thoroughly mixed prior to removing a small sample for pH, pigment and proximate analysis determinations. The sample was reground through a 0.13 in plate and then homogenized before analyses were made.

Results

Mean values for yields of lean, fat and skeleton and by-product weights are presented in Table 1. Live weights and carcass weights of ram and wether lambs were not significantly different. The percent of shoulder, leg, loin and rib which was considered suitable for chunked and formed roasts was higher for ram lambs than for wether lambs. The percentage of other lean which was obtained from the flank and breast was also higher for ram lambs than for wether lambs.

Fat trim from the carcasses of ram lambs made up 18.1 percent to 20.2 percent of the carcass weight compared to 27.3 percent to 28.8 percent of the carcasses of wether lambs. In contrast, skeletons of ram lambs made up higher proportions of the carcass weight than did skeletons of wether lambs. The data on carcass yields and yields of lean, bone and fat from ram vs wether lambs in this study are in agreement with other research.

Androgens are generally considered responsible for bone development, and it is, therefore, logical to expect rams to have heavier and larger bones than wethers. In the present study, when the bones (skeletons) with meat attached were run through the mechanical deboner, bone residue not recovered as MSL was 19.11 percent of the ram carcasses and 14.13 percent of the wether carcasses. The 27.32 percent to 28.84 percent fat trim for wethers and 18.08 percent to 20.29 percent fat trim for rams (Table 1) emphasize the need to reduce fat content in lambs.

Total by-product weights for the ram lambs (Table 1) were higher than for the wether lambs, and some of this difference was probably due to fat. Weight of blood and spleen when expressed as a percentage of the carcass weight did not vary among the four groups of lambs. However, the heads and pelts from ram lambs made up a higher percentage of the carcass weight than was the case for wether lambs.

All other viscera, a large proportion of which was the G.I. tract, was heavier for ram lambs than it was for wether lambs. The testicles of the ram lambs would have accounted for part of this difference. Higher pH values (Table 1) for longissimus muscle of ram lambs 2 h post-mortem than for wether lambs is interesting since the difference between rams and wethers was not maintained after 24 h.

Differences in yield of total lean suitable for chunked and formed roasts from the leg, loin, rib and shoulder favored ram lambs (Table 2). However, differences in composition of the trimmed lean between rams and wethers were small, indicating that the trimming of fat from muscles of the two groups was quite uniform. Higher yields of MSL from skeletons of wether lambs than from ram lambs is probably related more to the adjustment of the mechanical deboner on the day the MSL was produced than to any sex differences. Since bone residue of ram lambs contained more fat and moisture and less ash than bone residue of wether lambs, more pressure might have been placed on the meat and bone in the cylinder of the deboner when wethers were deboned than when rams were deboned, and the increased pressure could have resulted in higher MSL yields from wethers.

Differences in total pigments in lean and MSL between rams and wethers were small, indicating that color of restructured roasts made from ram and wether lambs should be the same when the fat content is similar. The increase in total pigment for MSL over that in the hand-trimmed lean is, for the most part, due to the addition of red marrow to the MSL during the deboning process, and the increase in total pigment can be used to estimate the amount of red marrow present in MSL. It was estimated that the MSL from ram lambs contained 91.4

percent muscle. The remainder was marrow and bone. Since calcium content of MSL from ram lambs in Table 2 was .35 percent (1.4 pct bone), the remainder left for marrow content of the MSL was 7.2 percent. Overall, the MSL produced from lamb skeletons in this study was of high quality and was well within the maximum 30 percent fat and .75 percent calcium levels and the minimum 14 percent protein levels permitted by the USDA (1982).

If restructured chunked and formed roasts and steaks are to be produced using hot-boned lamb, lambs high in lean and low in fat will need to be produced. All cuts suitable for chunked and formed roasts were used in this study, but in commercial practice, only boneless lean from the shoulder, MSL from shoulder bones and the neck may be economically feasible since the rib, loin and leg are usually in demand as bone-in cuts. Since more MSL could be incorporated into the roasts than would be produced, restructured flaked, ground or emulsified products would need to be made to utilize the additional MSL and lean from the breast and flank. Alternatively, the additional MSL and other lean could be used in sausages or in lamb patties.

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[1]Field is a professor of meat science, University of Wyoming; Cross is a professor of animal science, Texas A&M University (formerly research leader, Meats Unit, MARC); and Seideman is a research food technologist, Meats Unit, MARC.

Table 1.—Yield of lean, fat and skeleton and yield of by-products from hot-boned ram and wether lamb

	Slaughter groups of lambs			
Variable	Rams	Wethers	Rams	Wethers
Number	25	25	25	24
Liveweight, lb	107.6	95.9	100.8	103.1
Hot carcass wt, lb	54.4	53.6	53.7	55.8
Unaccounted for wt, lb[1]	[5]3.09	[3].73	[4]1.72	[4]1.54
Percentage of carcass wt				
Shoulder lean	[4]13.13	[3]12.02	[34]12.87	[3]11.97
Leg lean	[5]15.30	[3]12.62	[4]13.63	[34]13.01
Loin and rib lean	[4]5.32	[34]4.80	[34]4.79	[34]4.63
Other lean	[4]11.79	[34]10.54	[5]13.21	[3]10.32
Fat trim	[3]18.08	[4]27.32	[3]20.29	[4]28.84
Skeleton	[4]36.39	[3]32.80	[4]35.21	[3]31.22
By-products, pct[2]				
Blood	5.91	5.92	5.72	5.28
Head	[4]10.06	[3]8.98	[4]9.84	[3]8.52
Pelt	[4]24.11	[3]22.15	[4]24.64	[3]22.36
Liver	[4]3.87	[3]3.35	[3]3.15	[3]3.39
Spleen	.29	.26	.27	.29
Heart and lungs	[34]4.56	[34]4.32	[5]5.18	[45]4.94
All other viscera	[5]44.82	[3]36.00	[4]38.21	[34]36.57
Muscle pH 2 h post-mortem	[4]6.06	[3]5.94	[5]6.17	[34]5.98

[1]Difference between all carcass and by-product weights and liveweight.
[2]By-products are expressed as a percentage of the hot carcass weight.
[345]Means on the same line with different superscripts differ significantly ($P<.05$).

Table 2.—Composition and yield of lean, mechanically separated lamb (MSL) and bone residue from ram and wether lambs

Variable	Rams[1]	Wethers[1]
Composite lean[2]		
Yield, pct[3]	32.52	29.48
pH, 24 h post-mortem	5.7	5.7
Total pigments, mg/g	3.72	3.67
Protein, pct	18.38	18.49
Fat, pct	7.58	8.29
Moisture, pct	71.43	72.12
Ash, pct	1.06	.99
Composite MSL		
Yield, pct[4]	45.50	55.80
Yield, pct[5]	16.29	17.88
pH, 24 h post-mortem	6.6	6.5
Total pigments, mg/g	5.08	5.11
Protein, pct	15.12	14.78
Fat, pct	21.51	23.67
Moisture, pct	59.21	58.24
Ash, pct	1.75	1.77
Calcium, pct	.35	.39
Composite bone residue		
Yield, pct[4]	54.5	44.2
Yield, pct[5]	19.11	14.13
Protein, pct	20.31	21.49
Fat, pct	13.56	11.01
Moisture, pct	47.73	45.90
Ash, pct	17.46	20.06
Calcium, pct	6.37	6.81

[1]Each mean represents composite samples from two different groups of lamb.
[2]Lean from shoulder, leg, loin and rib with fat and connective tissue trimmed expressed as a percentage of the hot carcass weight.
[3]Percentage of hot carcass weight for lean from shoulder, leg, loin and rib which was considered suitable for chunked and formed roasts.
[4]MSL or bone residue expressed as a percentage of the skeleton and associated tissues.
[5]MSL or bone residue expressed as a percentage of the hot carcass weight.

Evaluation of Chunked and Formed Lamb Roasts Containing MSL, NFDM or Soy Isolate Which Were Processed with 1/2, 1, 1-1/2 Percent NaCl Under Different Conditions

M. Susan Brewer and Steve C. Seideman[1]

Introduction

In the past 30 years, American eating patterns have changed to include increased consumption of food products away from the home. As a result, growing sales volumes to the hotel, restaurant and institutional trade have encouraged the meat industry to develop restructured products which have the advantages of being manufactured exactly to specifications (i.e., size, fat composition, etc.) and are less expensive than intact-muscle steaks.

Over the years, research has been conducted on the ingredients, processing variables, chemical properties, rheological properties and sensory properties of restructured meat. Very little information is available on the use of mechanically separated meat in restructured products, and only a minimal amount of research is available on sensory evaluation of restructured meat by consumers. In addition, the qualities of restructured lamb made from hot-boned meat have not been addressed.

The purpose of this study was to obtain an untrained panel evaluation on restructured lamb roasts made with hot-boned and mechanically separated lamb (MSL). The influence of extenders, processing conditions and level of NaCl on palatability and composition of restructured lamb roasts was also determined.

Procedure

Forty-nine ram and 50 wether lambs, weighing approximately 99 lb each, were slaughtered as two groups of rams and two groups of wethers on four different days at the Roman L. Hruska U.S. Meat Animal Research Center. The major leg, loin, rib and shoulder muscles were hand-stripped from each carcass at 2 h post-mortem. Fat and obvious connective tissue were removed from the muscles. The meat was then placed in sealed polyvinyl chloride bags, packed in dry ice in cardboard boxes, crust-frozen and transported to the University of Wyoming.

Frames were immediately ground through a 0.5 in plate of a bone grinder and mechanically deboned using a Beehive deboner.

Trimmed leg, loin, rib and shoulder meat was ground through a 1.5 in kidney plate. Meat from all lambs was mixed for uniformity prior to making restructured roasts (Table 1). Coarse and MSL portions for the roasts were combined separately with the other ingredients listed in Table 1, mixed for 10 min and allowed to stand overnight at 39°F. The following morning, coarse, lean and MSL portions were mixed together for 5 min and then stuffed into 3.9 in fibrous casings. Roasts weighing 6.6 lb each were wrapped in freezer paper and placed immediately into a −22°F freezer where they stayed for up to 7 days before being heated (Figure 1). The following schedule was used: 140°F for 2 h; 160°F for 2 h; and 185°F until the internal temperature of the roasts reached 160°F. Roasts that were to be cooked immediately after stuffing were heated to 145°F, chilled to 39°F and reheated to 160°F internal temperature (Fig. 1).

Percentage cooking loss was determined using freshly stuffed weight and cooked weight after an overnight stand at 39°F. After the chilled cooked roasts were weighed, a 1.1 lb cross section was ground three times through a 0.13 in plate of a meat grinder and samples for the 2-thiobarbituric acid (TBA) test and proximate analysis were obtained.

Color and amount of muscle separation on the cut surface of a 1 in thick slice of each roast heated to 160°F and then chilled was evaluated independently by a four-member taste panel. Color scores ranged from 1 = lightest color cut surface to 5 = darkest colored cut surface, while muscle separation scores ranged from 1 = no evidence of muscle separation to 5 = extensive muscle separation. Warner-Bratzler shear measurements were obtained by averaging nine shear values from the core of cooked and chilled roasts.

An untrained panel consisting of 50-75 members was served wedges cut 0.2 in thick from the chilled, restructured roasts within a week after the roasts were prepared. Roasts were wrapped in freezer paper, held at 39°F and then sliced immediately prior to serving to panel members. Panelists scored four samples for tenderness, juiciness, flavor and texture using an eight-point scale. Roasts from each slaughter group were evaluated before the next slaughter group was processed. The samples were randomly coded and evaluated. Within panel sessions, two restructured roast samples contained 10 percent MSL and two samples contained 30 percent MSL. Within this arrangement, the order and time of day at which this combination of four roasts was served was randomized.

Least-squares procedures were used in a model that included NaCl level, MSL level, treatment and extender as discrete variables as well as all possible two-way interactions. No meaningful two-way interactions were found in this study.

Results

Panelists' scores for control roasts and for roasts containing NFDM or soy isolate are found in Table 2. No differences in tenderness between formulations existed. Roasts containing soy isolate were rated lower on juiciness, flavor and texture than control roasts or those containing non-fat dry milk. Shear values were not influenced by the addition of extender. Although the TBA value of 0.4 for roasts containing soy isolate was statistically lower than TBA values for control or NFDM extended roasts, the differences have very little practical value. All TBA values were too low to be of concern from a flavor standpoint.

Proximate analyses of the cooked roasts in Table 2 reflect differences in the amount of extender and moisture added to the formulations (see Table 1). Control roasts had less moisture and protein than roasts containing soy isolate, but they had an increased percentage of fat.

Tenderness ratings of restructured lamb roasts containing varying levels of NaCl were not different (Table 3). However, scores for juiciness and flavor were lower when roasts containing .5 percent NaCl were compared to roasts containing higher levels, indicating that untrained panel members prefer flavor and juiciness of products containing more than .5 percent NaCl. Muscle separation in restructured roasts decreased as salt level increased. The increase in Warner-Bratzler shear values with increased salt levels may also be related to higher binding ability of myosin (a meat protein) and other proteins at higher salt levels. Cooking losses tended to increase as salt level increased (Table 3).

Scores for tenderness and juiciness of restructured lamb roasts containing 30 percent MSL were slightly higher than those containing 10 percent MSL (Table 4). The panel tenderness scores coupled with the Warner-Bratzler shear values make it clear that the restructured lamb roasts containing 30 percent MSL are more tender than those containing 10 percent MSL.

Cooking losses in roasts containing 30 percent MSL were lower than those in roasts containing 10 percent MSL. Fat

content of the cooked roasts containing MSL was slightly higher for roasts containing 30 percent MSL than for roasts containing 10 percent MSL. This reflects a higher level of fat in the MSL than in the lean meat which was used to formulate the restructured roasts. The higher levels in the roasts with 30 percent MSL could have contributed to the higher scores for juiciness in the same roasts.

Least-squares means for restructured roasts which were frozen raw and cooked from the frozen state are compared to means for roasts which were stuffed into fibrous casings and cooked immediately (Table 5). The latter category of roasts were made with and without nitrite, as shown in Figure 1. The remainder of the formulation and all processing steps were identical for cooked and cured roasts. The untrained panel scores for all palatability traits studied were similar for all treatments. Lack of differences in palatability of roasts between treatments may have been a result of short storage periods of one week or less. Differences in muscle separation scores and shear values between cooked and cured roasts are significant.

Overall, of those factors evaluated in the present study, the type of extender used and level of NaCl had the most influence on panel scores for palatability, muscle separation and shear values, and composition of the cooked and chilled roasts. Roasts containing soy isolate and those containing .5 percent NaCl were least acceptable but were scored "slightly desirable" and were less than one point below other roasts in the study. It must, therefore, be concluded that acceptable restructured lamb roasts can be produced. Hot-boning can save time, labor and energy. The addition of MSL can decrease production costs considerably. In commercial practice, the boneless shoulder meat could be used in place of the boneless leg, loin, rib and shoulder which was used in this study. Meat from lean lambs would further lower costs because less trimming of the fat would be required.

[1]Brewer is a graduate assistant, University of Wyoming; and Seideman is a research food technologist, Meats Unit, MARC.

Table 1.—Formulations for restructured lamb roasts[1234]

Ingredient	Level of MSL 10 percent	Level of MSL 30 percent
Coarse portion		
Lean, lb	60.02	46.90
Water, lb	3.75	2.93
Seasoning, lb	0.95	0.74
Tripolyphosphate, lb	0.20	0.17
Fine portion		
Mechanically separated lamb, lb	6.66	20.11
Water, lb	1.65	2.47
Seasoning, lb	—	0.21
Tripolyphosphate, lb	—	0.04

[1]Each formulation was prepared for the four slaughter groups of lambs. Salt in the coarse and fine portions, including salt in the seasoning, was 2 percent, 1.5 percent, 1.0 percent and .5 percent of the total formulation for slaughter groups 1, 2, 3 and 4, respectively.

[2]Formulations containing calcium reduced dried skim milk (NFDM) were the same as those shown here but 3.5 percent NFDM and 3.5 percent water were added to the total and additional tripolyphosphate, salt and seasoning were added to account for the dilution with NFDM.

[3]Formulations containing soy isolate were the same as those shown here but 3.47 percent isolated soy protein powder (Ralston Purina Supro 620), 17.3 percent water and 17.3 percent structured isolated soy protein (Ralston Purina SPF 200) were added to the total and additional tripolyphosphate, salt and seasoning were added to account for the dilution with non-seasoned soy.

[4]One-third of the formulations including those in footnotes 1, 2 and 3 contained 149 ppm nitrite (see Fig. 1).

Table 2.—Least-squares means for restructured lamb roasts containing no extender, calcium reduced non-fat dried milk or soy isolate[1]

Variable	Control	Extender NFDM	Extender Soy
Number	24	24	24
Tenderness[2]	5.91	5.85	5.73
Juiciness[2]	^{7}5.53	^{7}5.54	^{6}4.99
Flavor[2]	^{7}5.37	^{8}5.52	^{6}5.03
Texture[2]	^{7}5.43	^{7}5.40	^{6}5.08
Color[3]	^{7}3.55	^{7}3.41	^{6}1.92
Muscle separation[4]	^{7}2.70	^{8}3.01	^{6}2.48
Warner-Bratzler shear, kg[5]	1.77	1.77	1.74
TBA	^{7}.6	^{7}.5	^{6}.4
Cooking loss to 160°F, pct	12.16	11.09	12.33
Cooked roasts			
Moisture, pct	^{6}65.79	^{7}66.66	^{7}67.02
Fat, pct	^{8}11.76	^{7}10.83	^{6}8.96
Protein, pct	^{7}18.42	^{6}17.91	^{8}20.56
Ash, pct	2.62	2.69	2.61

[1]This table includes roasts which were heated to 145°F, then chilled to 39°F and reheated to 160°F, as well as roasts which were frozen and then heated once to 160°F.

[2]Slices of chilled roasts 0.25 in thick were cut into 1 in squares and evaluated by 50 to 75 untrained panelists. 1 = extremely tough, dry or undesirable; 8 = extremely tender, juicy or desirable.

[3]1 = light, 5 = dark.

[4]1 = no muscle separation, 5 = extensive separation.

[5]Three 1 in diameter cores were sheared three times each. (1 kg = 2.2 lb.)

[678]Means on the same line with different superscripts are significantly different ($P<.05$).

Table 3.—Least-squares means for restructured lamb roasts containing varying levels of NaCl[1]

Variable	Level of NaCl 2.0 percent	1.5 percent	1.0 percent	.5 percent
Number	18	18	18	18
Tenderness[2]	5.86	5.79	5.85	5.84
Juiciness[2]	^{7}5.38	^{7}5.48	^{7}5.39	^{6}5.17
Flavor[2]	^{7}5.30	^{7}5.46	^{7}5.34	^{6}5.12
Texture[2]	5.25	5.43	5.27	5.21
Color[3]	^{6}2.72	^{7}3.10	^{67}2.95	^{7}3.06
Muscle separation[4]	^{6}2.39	^{67}2.71	^{67}2.72	^{7}3.11
Warner-Bratzler shear, kg[5]	^{7}1.85	^{7}1.98	1.73	^{6}1.49
TBA	^{8}.6	^{6}.3	^{9}.7	^{7}.4
Cooking loss to 160°F, pct	12.91	12.39	12.14	11.07
Cooked roasts				
Moisture, pct	^{6}65.75	^{7}66.98	^{67}66.35	^{7}66.88
Fat, pct	^{8}11.23	^{6}9.85	^{7}10.46	^{7}10.52
Protein, pct	^{6}18.43	^{6}18.72	^{6}18.89	^{7}19.80
Ash, pct	^{8}3.34	^{7}2.96	^{6}2.26	^{6}1.98

[1]This table includes roasts which were heated to 145°F, then chilled to 39°F and reheated to 160°F, as well as roasts which were frozen and then heated once to 160°F. NaCl levels of 2.0 percent and .5 percent were made with meat from ram lambs while the 1.5 percent and 1.0 percent levels utilized meat from wether lambs.

[2]Slices of chilled roasts 0.25 in thick were cut into 1 in squares and evaluated by 50 to 75 untrained panelists. 1 = extremely tough, dry or undesirable; 8 = extremely tender, juicy or desirable.

[3]1 = light, 5 = dark.

[4]1 = no muscle separation, 5 = extensive separation.

[5]Three 1 in diameter cores were sheared three times each. (1 kg = 2.2 lb.)

[6789]Means on the same line with different superscripts are significantly different ($P<.05$).

Table 4.—Least-squares means for restructured lamb roasts containing 10 or 30 percent mechanically separated lamb[1]

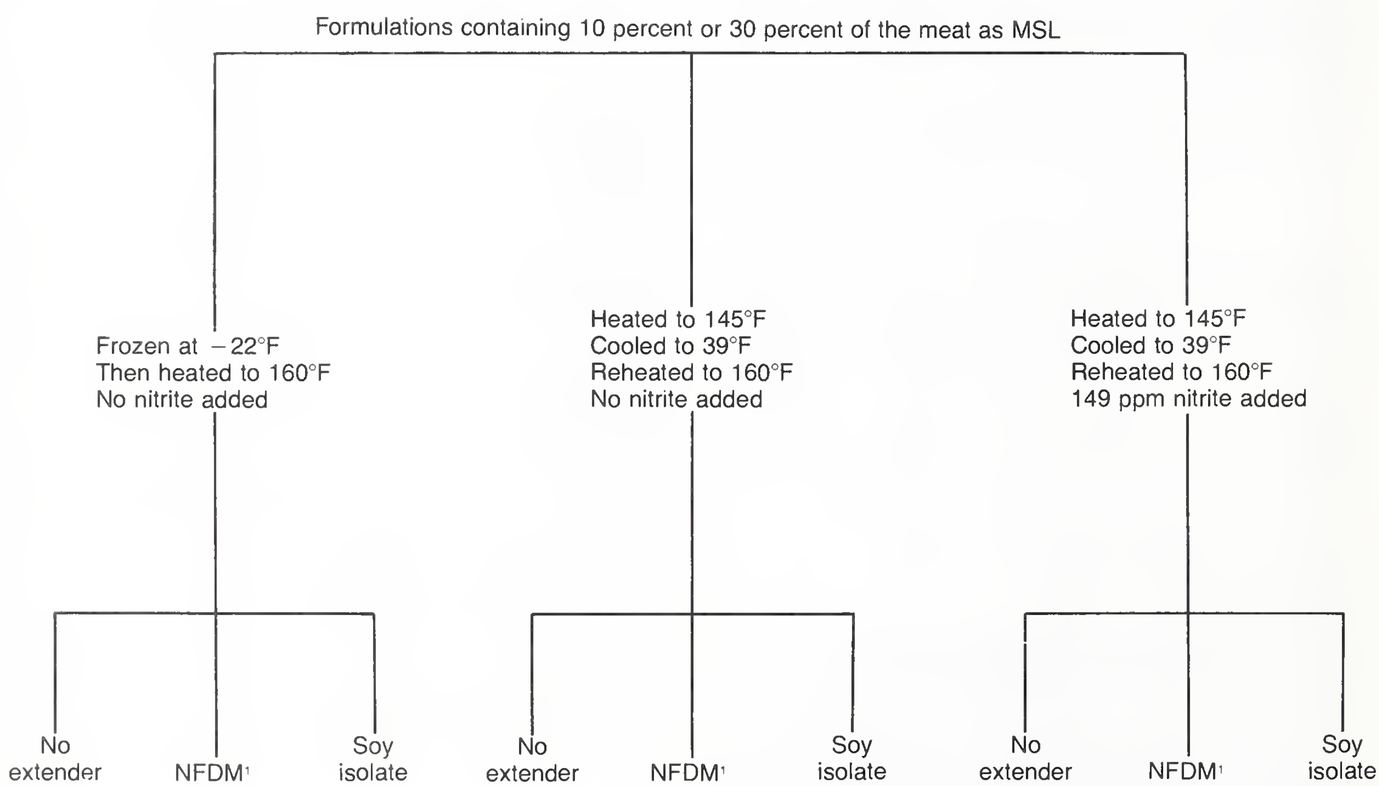
	Level of MSL	
Variable	10 percent	30 percent
Number	36	36
Tenderness[2]	[6]5.70	[7]5.96
Juiciness[2]	5.28	[7]5.42
Flavor[2]	5.31	5.30
Texture[2]	5.28	5.33
Color[3]	[7]3.08	[6]2.84
Muscle separation[4]	2.80	2.66
Warner-Bratzler shear, kg[5]	[7]1.86	[6]1.67
TBA	.5	.5
Cooking loss to 160°F, pct	[7]12.93	[6]11.33
Cooked roasts		
Moisture, pct	[7]66.75	[6]66.23
Fat, pct	[6]10.00	[7]11.04
Protein, pct	[6]19.14	[7]18.78
Ash, pct	2.58	2.70

[1]This table incudes roasts which were heated to 145°F, then chilled to 39°F and reheated to 160°F, as well as roasts which were frozen and then heated once to 160°F.
[2]Slices of chilled roasts 0.25 in thick were cut into 1 in squares and evaluated by 50 to 75 untrained panelists. 1 = extremely tough, dry or undesirable; 8 = extremely tender, juicy or desirable.
[3]1 = light, 5 = dark.
[4]1 = no muscle separation, 5 = extensive separation.
[5]Three 1 in diameter cores were sheared three times each. (1 kg = 2.2 lb)
[6,7]Means on the same line with different superscripts are significantly different ($P<.05$).

Table 5.—Least-squares means for restructured lamb roasts which were frozen, cooked or cured immediately after stuffing into fibrous casings

	Treatment		
Variable	Frozen[1]	Cooked[2]	Cured[2]
Number	24	24	24
Tenderness[3]	5.81	5.86	5.82
Juiciness[3]	5.44	5.31	5.31
Flavor[3]	5.30	5.25	5.36
Texture[3]	5.38	5.25	5.27
Muscle separation[4]	[6]2.66	[7]3.04	[6]2.49
Warner-Bratzler shear, kg[5]	[6,7]1.76	[6]1.68	[7]1.84
TBA	[7].61	[6].47	[6].41
Cooking loss to 160°F, pct	[6]9.45	[7]13.58	[7]13.35
Cooked roasts			
Moisture, pct	[7]67.37	[6]66.10	[6]66.00
Fat, pct	10.56	10.62	10.37
Protein, pct	[6]18.15	[7]19.37	[7]19.36
Ash, pct	2.62	2.59	2.69

[1]Roasts were frozen at −22°F, then cooked to 160°F.
[2]Roasts were cooked to 145°F, then chilled to 39°F and reheated to 160°F.
[3]Slices of chilled roasts 0.25 in thick were cut into 1 in squares and evaluated by 50 to 75 untrained panelists. 1 = extremely tough, dry or undesirable; 8 = extremely tender, juicy or desirable.
[4]1 = no muscle separation, 5 = extensive separation.
[5]Three 1 in diameter cores were sheared three times each. (1 kg = 2.2 lb)
[6,7]Means on the same line with different superscripts are significantly different ($P<.05$).



[1]NFDM = Non-fat dry milk.

Figure 1—Experimental design showing roasts used in the study. Each of the nine roasts shown on the bottom line was made with 10 percent MSL or 30 percent MSL for each of the four slaughter groups of lambs for a total of 72 roasts evaluated.

Sensory Evaluation of Fresh or Frozen Chunked and Formed Lamb Roasts

Janet C. Williams, M. Susan Brewer and Steve C. Seideman[1]

Introduction

The long-term downward trend in per capita consumption of lamb is related to shrinking supplies and rising prices (USDA, 1977). In addition, although fast food and institutional trades have become important market outlets for beef, pork and poultry meat, lamb has not yet been sold by fast food industries and is used sparingly in the institutional trade. Restructuring, which is done by binding chunks of meat together, may be useful in decreasing processing costs and in increasing the demand for lamb. The advantages of uniformity, precise cost control and easy storage and preparation which restructured meats offer should be incentives for increased use of lamb by the fast food and institutional trades.

The lower price of restructured beef, when compared to traditional retail cuts of beef, has been achieved by using lower quality grades and cuts that have the functionality and sensory properties of higher grades and cuts. Since very few lower grade lambs are marketed, the use of meat from ram lambs in restructured roasts was investigated. Ram lambs can be produced at a lower cost than wether lambs because of their more rapid gain and higher feed efficiency. In addition, ram lamb carcasses are leaner and require less trimming of fat prior to preparation of the restructured meat. Further reduction in cost might be achieved by utilization of mechanically separated lamb (MSL) because meat that is left attached to the bones after hand-boning could be economically removed by machine and incorporated into the roasts.

One of the most pressing problems associated with restructured meat is that of storage stability. Therefore, in the present study, the sensory properties of fresh chunked and formed lamb roasts are compared with the sensory properties of roasts which had been made and then frozen for six months. Factors such as level of MSL, level of NaCl and presence of nitrite, which could influence storage stability, were studied, and meat from ram lambs was compared to meat from wether lambs.

Procedure

A 2^5 (MSL level x sex x NaCl level x storage time x nitrite level) factorially arranged experiment with two replications was conducted (Fig. 1). Thirty-two restructured roasts were prepared from choice and prime wether lambs, and 32 restructured roasts were prepared from choice and prime ram lambs. The 25 wether and 25 ram lambs which furnished the meat were approximately 6 months of age, 101 lb in liveweight and had been fed a high-energy diet at the Roman L. Hruska U.S. Meat Animal Research Center. The leg, loin, rib and shoulder muscles furnished the coarse portion of the restructured roasts and was ground through a 1.5 in kidney plate. Meat from all 25 lambs in each group was mixed for uniformity prior to making the roasts. The fine portion for the roasts was MSL from the bones remaining after the lean was removed. The MSL from each group of lambs represented approximately 50 percent of the bone weight and was thoroughly mixed prior to use. Formulations which contained .5 percent or 1 percent NaCl, 10 percent or 30 percent MSL and 0 or 156 ppm nitrite are shown in Table 1. Immediately after leg, loin, rib and shoulder muscles were ground through a 1.5 in kidney plate and after MSL was obtained, portions of the meat were removed and 6.6 lb roasts were prepared and stuffed into fibrous casings. Roasts were heated using the following schedule: 140°F for 2 h; 160°F for 2 h; and 185°F until internal temperature of the roasts reached 145°F. The roasts were then showered in cold water until the internal temperature reached 90°F and chilled overnight at 39°F. The next morning roasts were wrapped in freezer paper and placed in a −22°F freezer for six months.

Fresh leg, loin, rib and shoulder muscles from the same lots of wether and ram lambs used to prepare the precooked roasts were placed in large cardboard boxes lined with freezer paper and frozen (−22°F). The MSL from the same lots used to prepare heated and stored roasts was also frozen at −22°F in the same freezer. After six months of frozen storage, coarse ground meat and MSL were removed from the freezer and the outer one inch from all surfaces was removed, even though no evidence of freezer burn was present. New roasts were prepared with the previously frozen meat following the same procedures used for the roasts which were made six months earlier. After the newly made roasts had been heated to 145°F and chilled overnight, they were compared to roasts which had been prepared six months earlier. Frozen roasts precooked to 145°F were thawed in a 39°F cooler. Two roasts (one from rams and one from wethers) which had been frozen for six months and two newly made roasts (one from rams and one from wethers) were weighed and then roasted at 375°F (AHEA, 1976) to an internal temperature of 160°F. The roasts were reweighed 15 min after removal from the oven to determine cooking loss. Roasts with different salt levels and different levels of MSL were served at random. All 32 roasts with no nitrite were evaluated prior to evaluating the 32 roasts which contained 156 ppm nitrite.

A nine-member trained sensory panel was used to evaluate hardness, juiciness, gristle, rancidity and number of chews. Experienced panelists were trained during five training sessions by evaluating actual samples and discussing each of the sensory attributes to be evaluated. Definitions for attributes evaluated were as follows: hardness — amount of force required to bite through the sample; juiciness — amount of moisture released after seven chews; gristle — amount of rubbery particles present after 10 chews; rancidity— any stale or undesirable flavor (this broad definition was accepted because of the difficulty which the panel experienced in differentiating between undesirable flavors in the lamb roasts); and chews — number of chews required before the sample was ready to swallow. Samples evaluated were cut into small squares and kept warm by holding them over water in double boilers until served.

Least-squares procedures were used in a model that included sex, NaCl level, MSL level, storage time and nitrite level as discrete variables. All possible two-way interactions were included in the model. Very few significant ($P<.05$) two-way interactions were present, and most of these were not considered meaningful.

Results

Differences in sensory scores between roasts made from wether lambs and those made from ram lambs did exist (Table 2). Roasts made from ram lambs had higher scores for both hardness and amount of gristle than roasts from wether lambs. The rather small differences in hardness and gristle in favor of chunked and formed roasts made with meat from wether lambs over those made with meat from ram lambs are comparable to differences in tenderness between rams and wethers which have been reported in earlier research. Many of the studies on tenderness show that palatability differences between rams and wethers exist for heavier and older lambs than those used in this study, so it was somewhat surprising to find that hardness and gristle differences existed between rams and wethers when meat from choice and prime lambs weighing

101 lb at slaughter were compared. Number of chews before a meat sample was ready to swallow were not different between roasts from rams and wethers. This measure of palatability could also be related to tenderness.

Results showed slightly higher rancidity scores for freshly made restructured roasts from rams (3.68) than from wethers (2.68). This could be a sex factor difference and not a difference in hydrolysis of fatty acids.

Small differences in sensory scores between roasts containing .5 percent NaCl and 1 percent NaCl existed (Table 2). The panel chewed samples from roasts containing 1 percent NaCl longer before swallowing than they did roasts containing .5 percent NaCl. The panel also scored roasts containing 1 percent NaCl as being higher in gristle. Perhaps the greater number of chews and the higher scores for gristle were associated with greater hardness of the roasts containing more NaCl, instead of being associated with actual differences in the amount of connective tissue. It is doubtful that an actual difference in the amount of connective tissue between roasts was present. A significant ($P<.05$) difference in sensory scores for juiciness also existed. Roasts which contained higher levels of NaCl tended to be more juicy. Much of the current research is emphasizing reduction in salt levels because of the association with hypertension and the reduction in shelf life. Since loss of flavor and lack of juiciness are often problems associated with restructured meat, continued use of some NaCl for the improvement in juiciness (Table 2), a decrease in cooking loss and an improvement in binding of the restructured meat that was observed seems justified.

When restructured lamb roasts containing 10 percent of the meat portion as MSL were compared to those containing 30 percent of the meat portion as MSL, scores for hardness, gristle and number of chews decreased as amount of MSL increased (Table 2). Since MSL has a fine texture and since all detectable connective tissue in the MSL is removed by the mechanical deboner, these findings were expected.

Sensory scores for rancidity, chews, hardness, juiciness and gristle by level of nitrite were not statistically ($P<.05$) different (Table 2). In addition, 2-thiobarbituric acid (index of rancidity) values were below one for restructured lamb roasts containing 156 ppm nitrite as well as for those without nitrite. The highly saturated fat contents of the lambs used in this study, plus the .3 percent tripolyphosphate which was added to all roasts, probably explains why no differences in sensory scores for rancidity or for other undesirable flavors such as "warmed-over" flavor exist. Therefore, lamb, because of its highly saturated fat content, appears to be well-suited for use in restructured roasts which are heated, then stored prior to being reheated and served hot. Meat from wether lambs containing 1 percent NaCl and .3 percent tripolyphosphate plus seasoning consistently received the highest sensory evaluations. Sensory scores for number of chews, hardness, and gristle decreased and scores for juiciness increased as level of MSL increased from 10 percent to 30 percent. Nevertheless, the lower level of MSL would probably be more acceptable when visual texture and appearance is considered because those roasts with 10 percent MSL had a texture more like boned and rolled lamb shoulders or legs.

[1]Williams is a professor of foods/nutrition, Division of Home Economics, and Brewer is a graduate assistant, Division of Animal Science, University of Wyoming; and Seideman is a research food technologist, Meats Unit, MARC.

Table 1.—Formulations for restructured lamb roasts which were served to a trained panel[1]

Ingredient	Level of MSL 10 percent	30 percent
Coarse portion (hand boned)		
Lean, lb	10.01	8.99
Water, lb	0.62	0.49
Seasoning, lb	0.16	0.12
Tripolyphosphate, oz	0.53	0.42
Fine portion (mechanically separated)		
Lamb, lb	1.10	3.35
Water, lb	.29	0.42
Seasoning, oz	—	0.56
Tripolyphosphate, oz	—	0.11

[1]Salt in the coarse and fine portions, including salt in the seasoning, was .5 percent and 1.0 percent of the total formulation. (See Fig. 1 for experimental design.)

Table 2.—Least-squares means and standard errors for trained panel scores on restructured lamb roasts (N = 64)

Variable	Rancidity[1]	Chews[2]	Hardness[1]	Juiciness[1]	Gristle[1]
Sex					
Wethers	[3]2.62	23.97	[3]3.42	5.76	[3]3.00
Rams	[4]4.55	24.98	[4]3.93	6.17	[4]3.74
Salt level					
.5 percent	3.34	[3]23.61	[3]3.29	[3]5.59	[3]2.82
1.0 percent	3.83	[4]25.33	[4]4.05	[4]6.34	[4]3.92
MSL level					
10 percent	3.65	[4]25.30	[4]3.99	[3]5.47	[4]3.76
30 percent	3.52	[3]23.65	[3]3.35	[4]6.46	[3]2.98
Storage time					
Fresh	[3]3.18	[3]23.77	[3]3.29	6.11	[3]3.08
Frozen 6 mo	[4]3.99	[4]25.18	[4]4.06	5.82	[4]3.66
NO_2 level					
None	3.60	24.35	3.53	5.82	3.11
156 ppm	3.57	24.59	3.81	6.11	3.64
Standard error	.19	.37	.16	.17	.14

[1]1 = low, 15 = high.
[2]Number of chews before a warm meat sample, approximately 1.5 cm^3, was ready to swallow.
[3,4]Means in the same column within categories with different superscripts are different ($P<.05$).

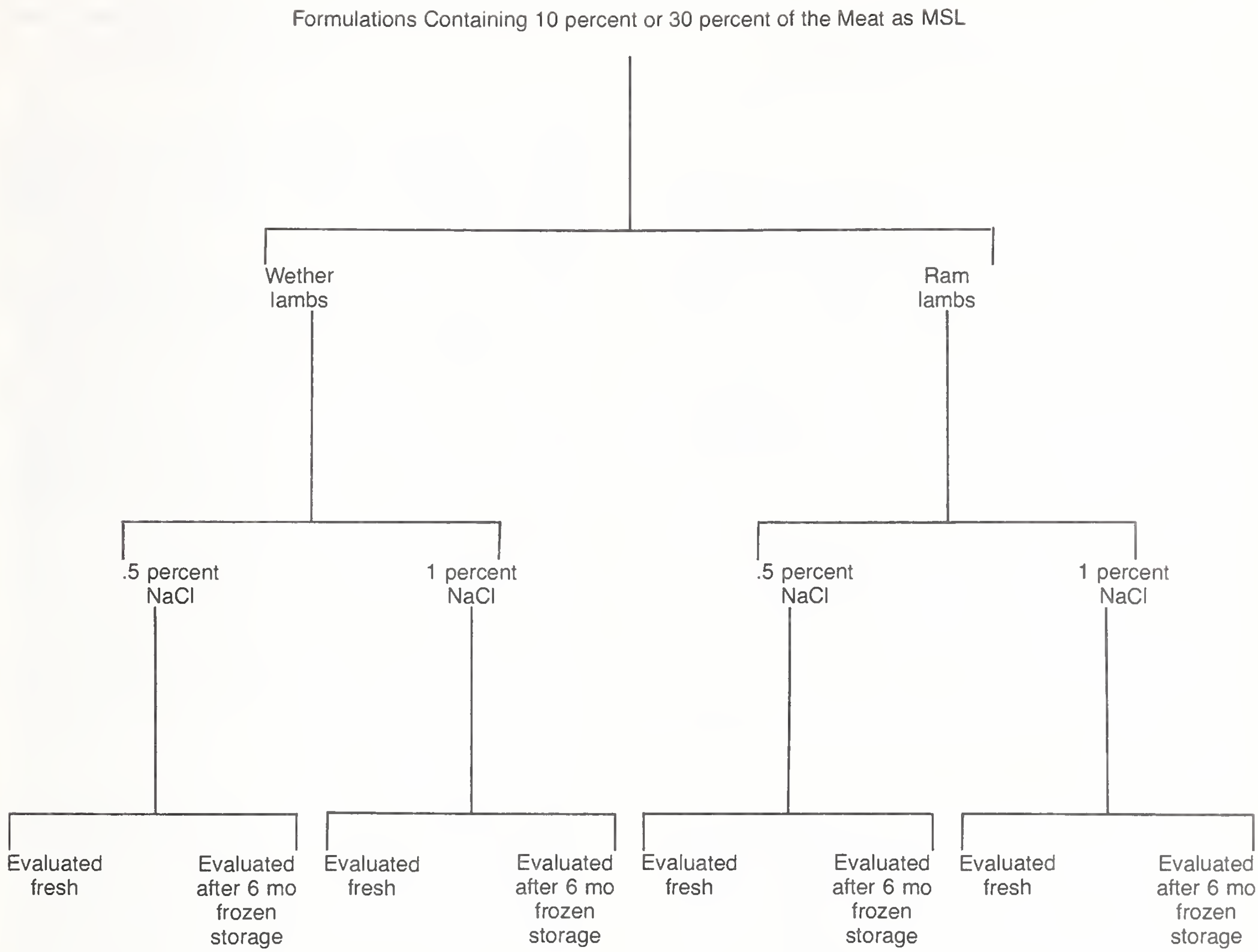


Figure 1—Experimental design showing roasts used in this study. Each of the eight roasts on the bottom line was made with 90 percent lean and 10 percent MSL as well as 70 percent lean and 30 percent MSL and the roasts were replicated in a subsequent trial for a total of 32 roasts. These 32 roasts were made without nitrite, but an identical group of 32 roasts containing 156 ppm nitrite was also made and included in the study.

The Influence of Storage on Lipid Quality of Chunked and Formed Lamb Roasts Containing Mechanically Separated Lamb

Kathleen A. Petro, Glenn J. Miller and H. Russell Cross[1]

Introduction

Lipid oxidation in restructured meat is one of the more important factors responsible for quality loss during storage. It results in the formation of off-flavors and odors, reduction or destruction of essential fatty acids and in formulation of brown pigments. In addition, lipid hydroperoxides and free radicals formed during oxidation have been implicated in a number of clinical conditions and in aging processes.

Peroxidation of lipids and development of rancidity in mechanically separated meat (MSM) may occur at a faster rate than in hand-boned meat because bone marrow, which is part of MSM, contains more unsaturated fatty acids. Large amounts of oxygen are incorporated into MSL during extrusion and this, plus the additional hemoglobin from red marrow, may further promote pigment and lipid oxidation. Most of the work with lipid oxidation of MSM has been with poultry and pork, which are relatively high in unsaturated fatty acids when compared to lamb. Very little information is available on the stability of lamb fat in processed products. Since saturated fatty acids in lamb are the most resistant to oxidation when compared to unsaturated fatty acids of pork and poultry, lamb fat should be less susceptible to autoxidation.

The purpose of this study was to determine the extent of lipid autoxidation during storage in chunked and formed restructured lamb roasts containing mechanically separated lamb (MSL).

Procedure

A total of 50 choice and prime grade ram lambs and 49 choice and prime grade wether lambs weighing approximately 101 lb each furnished hand-boned lean and MSL for this study. The leg, loin, rib and shoulder muscles furnished the coarse portion of the restructured roasts and was ground through a 1.5 in kidney plate. The fine portion for the roasts was MSL from the bones remaining after hot-boning muscles at 2 h postmortem. All roasts were formulated to contain NaCl, seasoning and .3 percent sodium tripolyphosphate. Roasts weighing approximately 1.4 lb each were prepared and stuffed into 3.9 in diameter fibrous casings. The experimental design showing cooking, curing and storage procedures for roasts evaluated in this study are given in Figure 1. Roasts to be frozen at −22°F were wrapped in freezer paper and stored for 1, 30 or 180 days. The roasts were then removed from the freezer and cooked to 160°F internal temperature from the frozen state. All other roasts were placed in an oven immediately after stuffing and precooked to 145°F before they were chilled to 39°F and then reheated to 160°F. The schedule for roasts cooked from the frozen state and those precooked before reheating was as follows: 140°F for 2 h; 160°F for 2 h; and 185°F until an internal temperature of 145° or 160°F was reached. The roasts were then showered in cold water until the internal temperature reached 90°F and chilled overnight at 39°F. The next morning the roasts were vacuum-packaged and stored for the time and at the temperature outlined in Figure 1. After the appropriate length of storage, portions of the roasts were removed and ground three times through a small grinder plate and thoroughly mixed before sampling.

Samples of the roasts were subjected to a dry column lipid extraction procedure to determine total lipid, phosphorus, free fatty acid (FFA), gas chromatographic analysis, and peroxide oxygen values. Small samples of the roasts were used for analysis of TBA values, expressed as parts per hundred (pph) of lipid to eliminate some of the variability due to differences in fat levels which often exist when these values are expressed on a fresh tissue basis.

Results

Both ground meat and MSL were assayed separately for several parameters prior to preparing the 90:10 and 70:30 mixtures. Values for total lipid, phospholipids (PL), thiobarbituric acid (TBA), peroxide oxygen value (POV) and free fatty acids (FFA) are found in Table 1. All values are expressed in terms of pph total lipid. As expected, MSL contained more total lipid and the lipid contained less PL, indicating a higher proportion of triglycerides. There was little indication of autoxidation as determined by POV and FFA values. All TBA values would be less than one if the values were based upon the total samples instead of the lipid in the sample. Fatty acid composition of lipids from ground meat and MSL indicated that MSL lipid contained more FFA than ground meat lipid. The FA compositions of ground meat lipid and MSL lipid, however, were similar within the ram and wether groups. There were no indications that the MSL lipid might increase levels of polyunsaturated FA to any large extent. These FA are intimately related to rate of autoxidation. Wether lamb tissue lipids contained less of the branched-chain and odd-numbered FA than lipids from ram lambs.

Cooked roasts of the 90:10 mixture appeared to contain less total lipid than did those of the 70:30 mixture. Cooking roasts once to 160°F from the frozen state apparently had little influence upon total lipid levels when values were compared to roasts which were precooked, then chilled and reheated.

Phospholipids have been implicated as being the lipids in meat most responsible for autoxidation due to their high levels of polyunsaturated fatty acids. During the storage trials there was little evidence of any change in lipid PL among the different cooking treatments or storage times.

Values for TBA and POV are used to assay extent of lipid autoxidation. In this storage study there is little evidence that extensive lipid oxidation had occurred for any of the cooking treatments or storage times. However, in many cases, the highest TBA and POV values were obtained from lipid samples of roasts stored for the longest periods of time.

Lipid FFA values provide a measure of glycerolipid hydrolysis and it has been reported that FFA undergo autoxidation more readily than esterified FA. Cooking prior to storage may have increased lipid FFA, at least in the case of 70:30 ram lamb roasts and wether lamb roasts. In all cases, lipid from roasts stored for 90 days at 39°F had the highest FFA when compared to other values, and lipids from ram lambs had higher FFA values than those from wether lambs. Since there was little change in lipid PL during storage, the increases in FFA were probably due to triglyceride hydrolysis. The increases of lipid FFA were quite small in terms of total lipid present. The results of this study indicate that MSL can be utilized for preformed roasts which will have an acceptable shelf life.

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[1]Petro is a research technician in the Nutrition Unit, MARC (formerly a graduate assistant, University of Wyoming); Miller is a professor of animal science, University of Wyoming; and Cross is a professor of animal science, Texas A&M University (formerly research leader, Meats Unit, MARC).

Table 1.—Lipid values of uncooked mixtures used for preparation of roasts[1]

	Ram		Wether	
Value[2]	Lean[3]	MSL[3]	Lean[3]	MSL[3]
Total lipid	8.0	24.2	7.3	25.1
PL	5.7	3.9	6.0	4.4
TBA	5.1	2.7	7.0	5.4
POV	0.0	0.0	0.0	0.0
FFA	6.7	5.9	7.5	4.7

[1]Average of two analyses.
[2]Total lipid expressed as parts per hundred (pph) fresh sample; PL (phospholipids), TBA (thiobarbituric acid) and POV (peroxide oxygen value) expressed as pph lipid; FFA (free fatty acids) expressed as a millimoles/100 g lipid.
[3]Lean refers to ground meat and MSL to mechanically separated meat.

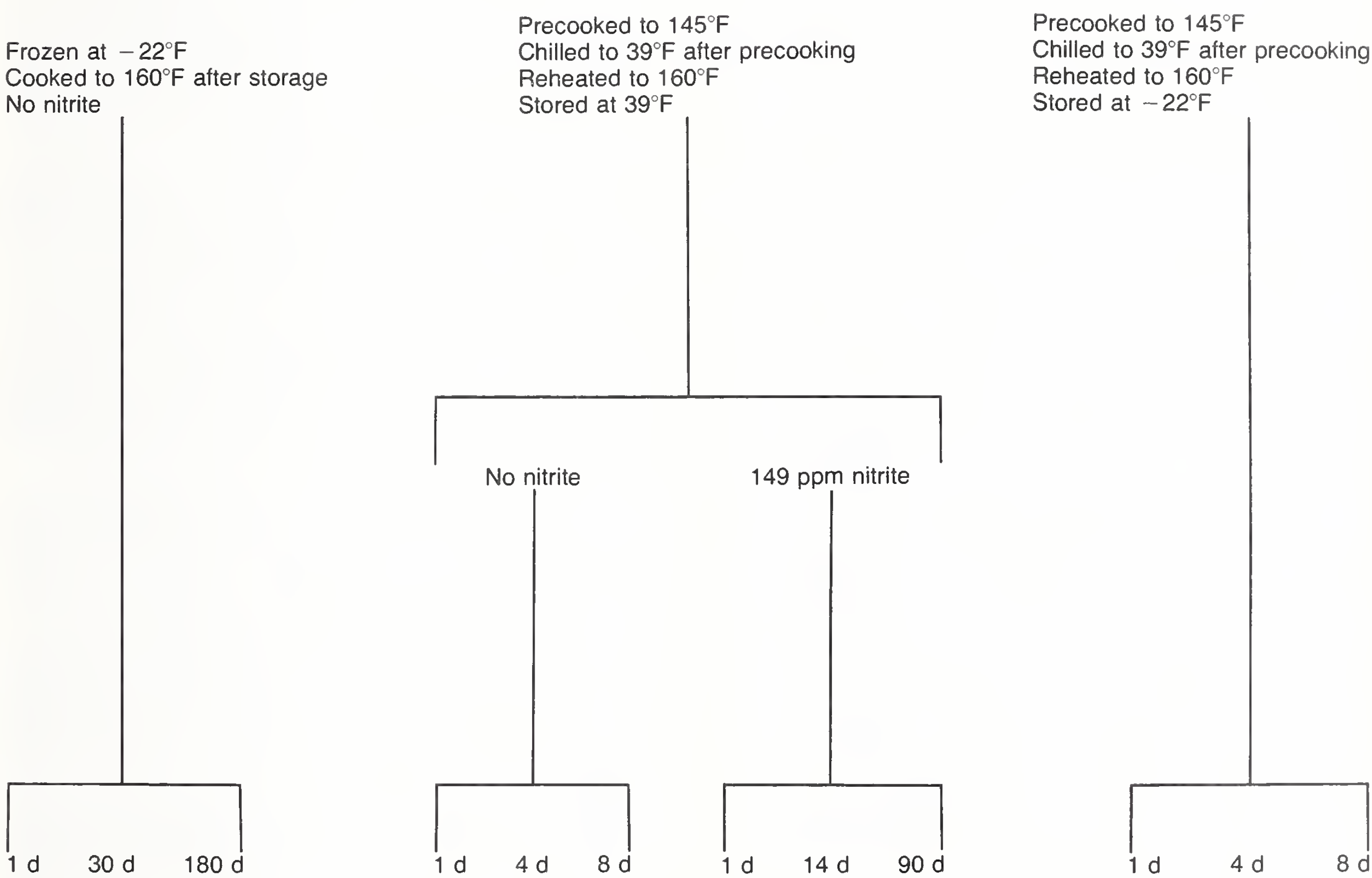

Figure 1—Experimental design showing cooking, curing and storage procedures for roasts studied. Each of the 12 roasts listed on the bottom line was made with meat from ram lambs or meat from wether lambs and each was made with 10 percent MSL or 30 percent MSL. All cooking and storage treatments were replicated.

Production Factors Affecting Lamb Carcass Composition and Meat Flavor

John D. Crouse, Cal L. Ferrell and Ray A. Field[1]

Introduction

The sheep industry is being advised to increase lamb production efficiency and lamb product availability by increasing slaughter weights of market lamb. Harrison and Crouse have shown that, from the standpoint of feed efficiency, the production of heavyweight, market ram lambs on high-energy density diets is profitable. However, investigators have observed that carcasses from heavyweight (>140 lb) ram lambs are often soft and oily, and many have undesirable aroma and flavor characteristics. Ram lamb carcasses have greater quantities of unsaturated fatty acids that result in soft, oily fat depots.

This study was undertaken to examine production factors that may influence the composition and flavor of meat from heavyweight market lambs as compared to that from lightweight lambs. Breed, diet, sex, location fed and interactions were additional factors studied.

Procedure

Seventy-eight Suffolk-sired and 75 Rambouillet-sired lambs out of Finn by white-faced (mixed breeding) crossbred ewes were either castrated or left intact; fed a high- or a low-energy density diet at the University of Wyoming Experiment Station, Laramie (UWY), or at the Roman L. Hruska U.S. Meat Animal Research Center (MARC); and slaughtered in two weight groups.

Lambs were approximately 90 days old at the start of the trial and weighed an average of 50 lb. The lambs were fed in eight pens of 10 lambs at each location. The eight pens included two diets, two sexes and two replications. All feed for the experiment was purchased in one lot at MARC. High-energy (91 pct concentrate) and low-energy (86 pct concentrate) diets were formulated, prepared and pelleted at MARC, and feed was shipped to UWY.

When the average weight of lambs in all treatments reached 137 lb, one-half of the lambs were slaughtered (slaughter group 1). The remaining lambs were slaughtered at an average weight of 168 lb, 63 days later (slaughter group 2).

After a 24-h carcass chill, maturity, quality grade, estimated kidney and pelvic fat percentage and leg conformation were determined. Subjective scores also were assigned for fat color, fat firmness and buckiness (degree of masculinity).

Organoleptic tests were conducted on muscles from racks. Muscles were thawed at 36°F for 48 h, boned and stripped of all subcutaneous and intermuscular fat. Lean and fat were mixed at a 4:1 ratio to standardize physical quantities of fat in samples presented to sensory panelists.

Results

Breed. Suffolk-sired lamb carcasses were heavier and possessed larger rib eye areas than Rambouillet-sired lambs. Measures of external fat deposition (e.g., fat thickness) were not influenced by breed. Yield grades (YG; USDA, 1969) also tended to be lower for carcasses from Suffolk-sired lambs than carcasses from Rambouillet-sired lambs.

Fat of carcasses obtained from Suffolk-sired lambs was more yellow than that of Rambouillet-sired lambs. No differences in fat firmness were observed between breeds. Suffolk-sired lambs were, however, judged to have more pronounced secondary sex characteristics than Rambouillet-sired lambs. Suffolk-sired lambs graded higher than Rambouillet-sired lambs. Breed did not influence flavor of cooked lamb meat.

Diet. Differences in performance between ram and wether lambs were greater with the high-energy diet (rams = 0.516 lb/day vs wethers = 0.421 lb/day) than with the low-energy diet (rams = 0.430 lb/day vs wethers = 0.379 lb/day). Differences in ADG were reflected in slaughter weights.

Lambs fed the high-energy diet had heavier slaughter weights than lambs fed the low-energy diet. Lambs fed the high-energy diet also had greater quality grades and higher YG (lower cutability). Lambs fed the high-energy diet had softer, yellower fat than lambs fed the low-energy diet.

Flavor of ground meat from lambs fed the low-energy diet was more intense than that of ground meat from lambs fed the high-energy diet. In previous studies, meat from lambs fed roughage diets received more undesirable flavor scores than that from lambs fed various levels of concentrates.

Sex condition. Fat of ram lambs became more yellow from the first to the second slaughter group, whereas wether lamb fat became whiter. Similarly, ram lamb fat became softer from the first to the second slaughter group, while wether lamb fat became firmer. Ram lambs also increased in maturity at a faster rate than wether lambs. Meat from rams had a more intense flavor.

Location. Lambs fed at UWY gained faster and were heavier at slaughter and fatter than lambs fed at MARC. Increased fatness of lambs fed at UWY was associated with increased live-animal weights. No differences in cooked meat flavor due to location were observed.

Slaughter group. Live-animal weights the day before slaughter were 137.7 lb for lambs in slaughter weight group 1 and 167.2 lb for those in slaughter weight group 2. Lambs in slaughter weight group 2 had higher quality grades, higher buckiness scores, greater fat deposition and larger rib eye areas. Fat firmness, fat color and organoleptic traits were not affected by slaughter weight group.

Data from this study show that the feeding of high-energy diets to heavy ram lambs is the best way to exploit their superior potential for growth and, at the same time, to produce meat with less intense flavor. Production of greater amounts of soft, yellow fat, which detracts from industry and consumer acceptance, is a distinct disadvantage of carcasses from heavy ram lambs fed high-energy diets.

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[1]Crouse is the research leader, Meats Unit, MARC; Ferrell is a research animal scientist, Nutrition Unit, MARC; and Field is a professor of meat science, University of Wyoming.

The Relationship of Carcass and Meat Lipid Characteristics to Lamb Meat Flavor

John D. Crouse, Jan A. Busboom and Glenn J. Miller[1]

Introduction

Lamb sex, diet and carcass weight have been associated with variation in carcass composition and palatability. Carcasses obtained from heavy ram lambs are often soft and oily, and many have intense flavor characteristics. These observations support previous findings that ram lamb carcasses have greater quantities of unsaturated fatty acids than wether lambs, which results in soft, oily fat depots. Studies have shown that feeding lambs a high-energy diet decreases lamb fat firmness. However, low-energy diets, composed chiefly of legumes, have been implicated in undesirable flavor scores.

This study was undertaken to determine the relationship of quality characteristics and fatty acids composition of the lamb carcass with flavor of cooked meat and carcass grades.

Procedure

Thirty-two Suffolk-sired and 32 Rambouillet-sired male lambs out of Finn by white-face ewes were castrated or left intact, fed a high- or low-energy diet, fed at the University of Wyoming (UWY) or the Roman L. Hruska U.S. Meat Animal Research Center (MARC), and slaughtered in two weight groups. Management of lambs was previously described in a report entitled "Production Factors Affecting Lamb Carcass Composition and Meat Flavor."

Hot carcass weight was taken on the kill floor within 20 min after slaughter. After a 24 h carcass chill, maturity, quality grade, and yield grade (USDA, 1969) were determined by UWY and MARC personnel. Subjective scores also were recorded for fat color, fat firmness, and buckiness.

Untrimmed racks were broken from the carcasses immediately after color and firmness evaluations, and a subcutaneous fat sample was removed from over the rib eye muscle and lower rib for fatty acid analysis. Layers of inner and outer subcutaneous fat were easily distinguished, and fat samples were selected from the visibly softer outer layer of subcutaneous fat.

Total lipid in the 64 subcutaneous fat samples was extracted and purified. Straight-chain fatty acids were designated A:B, where A represents the number of carbons and B, the number of double bonds. Branched-chain fatty acids were designated C ME A:B, where C represents the position of the methyl group (counting from the carboxyl end). The profiles for both medium-chain fatty acids (10:0, 4 ME 10:0, 11:0, 2 ME 11:0, 12:0, 2 ME 12:0, 13:0, 4 ME 13:0, 14:0, 4 ME 14:0, 15:0 and 4 ME 15:0) and long-chain fatty acids (16:0, 16:1, 17:0, 12 ME 17:0, 18:0, 18:1, 18:2 and 18:3) were obtained by the gas chromatography methods. Peroxide numbers, an objective measure of rancidity, were determined on fat samples.

Flavor panel test procedures were previously described in a paper entitled "Production Factors Affecting Lamb Carcass Composition and Meat Flavor."

Results

Lamb carcasses were evaluated as high choice with a yield grade of 4.00. A large amount of variation in carcass fatness, yield grade, fat color, fat softness, and buckiness was observed. Quality grade and hot carcass weight had considerably less variation than other carcass traits.

The mean sensory panel flavor score indicated that flavor was not intense and did not vary greatly among carcasses. Peroxide numbers were low but highly variable. Large amounts of variation in peroxide values may be expected, since fatty acid saturation varied among carcasses, and fats that are highly unsaturated generally have higher peroxide values than those that are saturated.

Twenty fatty acids were identified. The bulk of the fat sampled was 16:0, 18:0 and 18:1. Fatty acid 18:1 was by far the most abundant. Fatty acids 16:0, 18:0 and 18:1 were the most variable. Fatty acids with fewer than 16 carbons (medium-chain fatty acids) made up a relatively small amount of the fat sample. Observations indicate that medium-chain fatty acids are more variable in quantity than long-chain fatty acids relative to the amount present. Sex condition affected the quantities of all fatty acids observed except 10:0, 14:0, 4 ME 14:0, 18:2 and 18:3. Fat from ram lambs was higher in branched-chain and in shorter odd-numbered fatty acids but lower in 16:0 and 18:0 than fat from wethers. Feeding lambs a high-energy rather than a low-energy diet also increased levels of odd-numbered and branched-chain fatty acids. Weight group, breed, and location fed had little effect on fatty acid composition, fat firmness or fat color.

Correlations between carcass traits and fatty acids are shown in Table 1. Fatty acids 18:1 and 18:3 had the greatest overall correlations with taste panel flavor score ($r = -0.33$ and $r = 0.33$, respectively). Decreased quantities of 18:1 and increased quantities of 18:3 were associated with increased flavor intensity. The overall correlation of -0.15 observed between the amount of 18:2 and flavor score indicated a slight tendency for decreases in quantities of 18:2 to be associated with increased flavor intensity.

Amounts of 10:0 and 4 ME 10:0 were not significantly associated with flavor intensity. Previous evidence indicated that the 4-methyl-substituted C9 and C10 acids were primarily responsible for the sweaty mutton odor noted in lamb meat. The sweaty mutton odor, however, may not be associated with the lamb flavor component evaluated in the present study. Results of analyses in the present study indicate that little variation in lamb flavor intensity is associated with fatty acid composition. Since variation in flavor intensity was observed among subclass means for sex and diet, factors other than those observed in the present study must contribute to lamb flavor.

Carcass traits (Table 1) were not correlated with flavor. Carcass measures of quantities of fat, as measured by yield grade, quality grade and fat thickness, may not have been expected to be associated with flavor intensity since quantities of fat in sensory panel samples were standardized. Variation in palatability, therefore, would have been associated with variation in fat composition and not variation in quantities of fat.

Covariations in fat composition associated with fat quantities are reflected in correlations presently reported. Greater quantities of fatty acids 17:0, 18:1 and 18:2 were associated with increased carcass fatness.

[1]Crouse is the research leader, Meats Unit, MARC; Busboom is a research associate, Michigan State University (formerly a research associate at University of Wyoming); and Miller is a professor of animal science, University of Wyoming.

Table 1.—Correlations between lamb carcass traits and fatty acids[1]

Traits	Flavor intensity	Quality grade
Carcass traits:		
Quality grade	−0.08	—
Yield grade	−0.05	0.45
Fat softness	0.09	0.16
Maturity	−0.07	0.25
Fat thickness	0.07	0.04
Fat color	0.06	−0.11
Buckiness	−0.05	0.31
Hot carcass weight	0.08	0.52
Peroxide	0.01	−0.11
Fatty acids:		
10:0	0.02	−0.09
4 ME 10:0	−0.03	0.14
11:0	0.04	0.04
2 ME 11:0	0.03	0.00
12:0	−0.02	−0.09
2 ME 12:0	0.01	0.05
13:0	−0.03	0.08
4 ME 13:0	0.02	0.02
14:0	0.07	−0.37
4 ME 14:0	−0.02	0.15
15:0	0.05	−0.05
4 ME 15:0	0.00	0.12
16:0	−0.05	−0.22
16:1	0.10	−0.18
17:0	−0.12	0.41
2 ME 17:0/17:1	−0.03	0.08
18:0	0.01	−0.16
18:1	−0.33	0.38
18:2	−0.15	0.27
18:3	0.33	−0.31

[1]Values reported (correlations) can range from zero to ± 1, with 1 being the highest possible correlation.

The Effects of Lamb Finishing Diet, Sex Condition and Slaughter Weight on the Flavor Profile of Meat

John D. Crouse, Cal L. Ferrell and H. Russell Cross[1]

Introduction

Flavor is an important aspect of meat quality and sometimes is even used as the determining criteria in acceptance or rejection of the product. The sheep industry is currently seeking methods to increase efficiency of lamb production. These production methods involve finding ways to increase market weights of lamb, with likely consequences of increased product availability and reduced consumer costs. To increase market weights, the industry may consider changing its genetic base, feeding to older ages and implementing new diets and management practices including the production of intact males. The effects of these genetic and environmental changes on lamb flavor need to be assessed to ensure a product acceptable to a broad segment of the population.

The objectives of this experiment were: 1) to determine the effects of sex, diet and slaughter weight on the flavor and aroma of cooked lamb meat and 2) to identify and characterize flavors and odors observed by use of a flavor profile panel.

Procedure

One hundred thirty-four Suffolk- and Columbia-sired ram and ewe lambs out of Finn x Rambouillet ewes were *ad libitum* fed one of two isoprotein, isocaloric diets containing alfalfa or soybean meal as a protein source.

Lambs were about 90 days of age at the initiation of the trial, and ram and ewe lambs weighed about 53 and 51 lb, respectively. Lambs were slaughtered at average live-animal weights of 110 or 152 lb. The two live-animal slaughter weights represent the two slaughter groups in the factorial arrangement.

A flavor profile panel was selected and trained. Amplitude of lamb chop aroma and flavor measured how characteristic the flavor was of lamb and was scored 1 (very low) to 4 (high). Flavor characteristic description terms — ammonia, astringent, bitter, browned, gamey, grassy, metallic, muttony, musty, sour and sweet — were scored 1 (very weak) to 5 (very intense). Aftertaste was scored by a hedonic rating with 1 (good) to 3 (poor). Descriptive terms were also ranked in the order in which they were perceived.

A sample of subcutaneous fat from each rib was thawed at an ambient temperature of 41°F over a 24-h period. Fat samples were maintained at 158°F in a double boiler and scored for aroma amplitude (4 = very characteristic of fresh lamb, to 1 = very low) by the sensory panel.

Results

The effects of diet on carcass characteristics tended to support previous observations that lambs fed high concentrate diets produce carcasses with soft and yellow fat. Overall means for percentage thaw loss, percentage total loss and cooking time were .77 percent, 25.7 percent and 24.5 min, respectively. Percentage total losses tended to be greater for the trimmer Columbia chops than the Suffolk chops (2.6 percentage points). Neither diet nor sex had an effect on total loss or cooking time, although ewes tended to produce chops with greater purge losses.

Columbia lambs tended to produce chops with a more sour flavor than chops produced by Suffolks. "Browned" and "gamey" were the first and second flavor notes, respectively, observed by panelists. "Ammonia" was the third flavor note observed for chops produced by Suffolks, as compared with "sweet" for Columbia.

Chops produced on the soybean diet possessed a more musty flavor and aftertaste than those produced on the alfalfa diet. These differences were restricted to within the ram sex. Flavor of chops from rams possessed more intense ammonia note and tended to be more muttony than chops from ewe lambs when the lambs were fed the soybean diet. Amplitude of fat aroma was greater in chops produced on the soybean diet. All flavor notes were similar between the two diets. Browned flavor was the first flavor note to be observed in chops from lambs fed alfalfa and soybean diets.

Chops obtained from ewe lambs possessed aroma and flavor more characteristic of lamb. Ammonia flavor in ram chops was more intense. Chops obtained from ram lambs were less metallic in flavor than chops from ewe lambs when fed alfalfa, but more intense when fed soybean meal. Ewe lamb chops, in general, possessed a more intense browned flavor.

An increase in gamey flavor was the only effect slaughter group had on lamb flavor. No variation in mutton flavor or flavor amplitude was associated with time on feed.

Observations of cooked lamb meat by flavor profile panel indicate that sire breed of lamb did not affect flavor in this trial. Production of ram lambs on supplemental soybean meal can be expected to result in lamb chops possessing a more musty and muttony flavor than rams fed supplemental alfalfa. Magnitude of musty and muttony flavor notes will decrease with longer feeding periods. "Browned" followed by "ammonia" are the first and second flavor notes observed regardless of diet.

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[1]Crouse is the research leader, Meats Unit, MARC; Ferrell is a research animal scientist, Nutrition Unit, MARC; and Cross is a professor of animal science, Texas A&M University (formerly research leader, Meats Unit, MARC).

Clinoptilolite or Zeolite NaA Supplementation to Corn, Corn-Fishmeal and Corn-Soybean Meal Diets for Growing Lambs

Wilson G. Pond[1]

Introduction

Naturally occurring zeolites are widespread in the U.S. and other countries as volcanic ash residues with potentially useful projection for agriculture. They are aluminosilicate crystalline rock with the capacity for binding cations such as NH_4^+(ammonia), K, Na, Ca and Mg. The NH_4^+-binding capacity of clinoptilolite is an attractive property for its potential application in ruminant nutrition and was the basis for a Canadian patent for the use of this natural zeolite in urea-containing diets for ruminants. Zeolite NaA, a synthetic zeolite, has similar NH_4^+-binding capacity *in vitro*.

The present work was designed to determine the effects of dietary clinoptilolite or zeolite NaA supplementation of dietary nitrogen level and of proteins of different solubilities in the rumen on weight gain, feed utilization, concentration of plasma urea-N, Ca and inorganic P and on carcass characteristics of growing lambs.

Procedure

Sixty-three Suffolk-sired growing ram and ewe lambs weighing an average of approximately 73 lb were randomly assigned within sex to the nine diets shown in Table 1. Samples of each diet were taken four times during the experiment for analysis; chemical composition of the diets is shown in Table 2. Lambs were kept individually in 3 x 4 ft pens with expanded metal floors in an enclosed, force-ventilated building and fed their respective dry diets *ad libitum* (7 lambs/diet) from metal self-feeders throughout a 10-week experiment. Individual body weights and cumulative individual feed consumption were recorded at 4, 8 and 10 weeks. Blood was sampled from the jugular vein after a 16-h fast at 0, 4, 8 and 10 weeks for determination of plasma urea-N, Ca and P (Gilford Diagnostics, 1978) concentrations. At week 10, 36 lambs (2 male and 2 female fed each diet) were slaughtered after an overnight fast. Hot carcass weight (dressed weight immediately after slaughter), cold carcass weight (weight after 72 h in 41°F cooler), leg conformation score, carcass quality score, kidney fat weight, kidney weight, liver weight and longissimus muscle cross-sectional area at the 10th rib were determined.

Results

Feed and weight gain data are summarized in Table 2. Body weight of males was greater than that of females initially and throughout the 10-week experiment (120 vs 100 lb final weight). Average daily weight gain to 4 weeks was greater for lambs fed diets containing soybean meal (SBM) or fishmeal (FM; 0.734 and 0.690 lb/day, respectively) than for those fed diets containing corn alone (0.582 lb/day; $P<.01$). Over the entire 10-week experiment, lambs fed FM and SBM had greater daily gain (0.569 and 0.549 lb/day) than lambs fed corn (0.439 lb/day). There was no difference at either 4 or 10 weeks in daily gain between lambs fed the two protein supplements. Neither clinoptilolite nor zeolite NaA had a significant effect on daily gain to 4 weeks or to 10 weeks, although lambs fed zeolite NaA in the presence of FM or SBM tended to have lower weight gains after 4 weeks and lambs fed clinoptilolite tended to gain faster throughout the 10-week experiment in the presence of FM or SBM than lambs fed supplemental protein without clinoptilolite (12.7 pct greater to 4 weeks and 11.5 pct greater to 10 weeks). Beneficial effects of dietary clinoptilolite on beef cattle, dairy cattle and sheep have been reported, based on observed changes in rumen fermentation patterns and rumen ammonia and urea levels.

Daily feed intake was greater in lambs fed FM or SBM than in lambs fed corn alone in the present experiment (Table 2). There were no interactions between diet and sex or between protein level or source and zeolite additions to the diet with respect to weight gain, gain/feed or feed intake. Gain per unit of feed consumed to 10 weeks tended to be greater for lambs fed FM than for those fed SBM or corn alone, but the difference did not reach statistical significance. There were no interactions between diet and sex or between protein source and zeolite addition to 10 weeks. Lambs fed clinoptilolite in the presence of FM tended to have a higher gain to feed ratio at 4 and 10 weeks than those fed clinoptilolite with corn alone or clinoptilolite with SBM.

Neither clinoptilolite nor zeolite NaA affected plasma concentrations of Ca, P, Na or Mg in previous work, but in the present experiment plasma P tended to be decreased and plasma urea-N increased in lambs fed zeolite NaA. Clinoptilolite had no effect on plasma urea-N or on plasma Ca or P, in agreement with previous observations. Lambs fed SBM or FM had higher plasma urea-N than those fed corn alone ($P<.01$) at weeks 4, 8, and 10, as would be expected due to higher N intake. Plasma urea-N was higher ($P<.05$) in lambs fed SBM than in those fed FM at weeks 4 and 10. Lambs fed SBM had significantly depressed plasma inorganic P at 8 and 10 weeks compared with lambs fed FM, suggesting the possibility of low P bioavailability, even though all diets contained adequate total P. The similar performance of lambs fed SBM and those fed FM as a protein supplement suggests no important differences between these two sources for growth of lambs fed on high-concentrate diets.

Carcass characteristics are summarized in Table 3. Cold carcass weight as a percentage of liveweight was unaffected by sex or diet. Leg conformation scores, percentage of kidney fat and carcass quality scores were not associated with any apparent important effects of diet or sex. Relative kidney and liver weights were greater for lambs fed FM or SBM than for lambs fed corn alone ($P<.01$) and for lambs fed SBM than for those fed FM ($P<.05$). Presumably, the larger kidneys for lambs fed SBM or FM than of lambs fed corn are related to the higher urea-N level of plasma and the metabolic activities of organs associated with its use.

The results of this experiment provide no evidence for differences in the growth and carcass characteristics of growing lambs fed FM compared with SBM as a protein supplement in a high concentrate corn-alfalfa meal diet from 73 lb body weight to slaughter. The data are suggestive of a beneficial effect on daily weight gain and feed efficiency of 2 percent clinoptilolite, but not of 2 percent zeolite NaA added to diets containing FM or SBM. Further work is needed to identify the nature and magnitude of changes in rumen fermentation and in energy and nitrogen utilization in growing lambs fed clinoptilolite in combination with FM or SBM as a protein supplement to high concentrate diets.

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[1]Pond is the research leader, Nutrition Unit, MARC.

Table 1.—Ingredient composition of diets

Ingredient	Diet designation:[1]	Corn(C)	Corn + CL	Corn + ZA	Corn + FM	Corn + FM + CL	Corn + FM + ZA	Corn + SBM	Corn + SBM + CL	Corn + SBM + ZA
		Composition (pct)								
Alfalfa meal	IFN 1-00-023	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Corn	IFN 4-01-935	84.85	82.85	82.85	73.55	71.35	71.15	71.05	68.85	68.65
Soybean meal	IFN 5-04-604				7.0	7.2	7.4	14.0	14.2	14.4
Menhaden fish meal	IFN 5-02-009				5.0	5.0	5.0			
Trace mineralized salt		.4	.4	.4	.4	.4	.4	.4	.4	.4
Calcium phosphate	IFN 6-01-080	1.0	1.0	1.0				.6	.6	.6
Vitamin ADE premix		.05	.05	.05	.05	.05	.05	.05	.05	.05
Clinoptilolite[2]			2.0			2.0			2.0	
Zeolite NaA[3]				2.0			2.0			2.0
Limestone		1.2	1.2	1.2	1.0	1.0	1.0	1.4	1.4	1.4
Total, pct		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated protein, pct[4]		10.2	10.0	10.0	15.2	15.2	15.2	15.2	15.2	15.2

[1]CL = clinoptilolite; ZA = zeolite NaA; FM = fish meal; SBM = soybean meal.
[2]Clinoptilolite provided by Richard Laudon, Double Eagle Petroleum and Mining Co., Casper, WY; Mined from Buckhorn, NM deposit, −50 mesh. R. A. Sheppard, USDI Geologic Survey, Denver, CO, characterized the clinoptilolite deposit used (Sheppard and Gude, 1982).
[3]Zeolite NaA provided by S. M. Laurent, Ethyl Corp., Baton Rouge, LA.
[4]Based on U.S.-Canada Feed Composition Tables, 3rd Ed., 1982. Corn, 93.3; alfalfa meal, 17.3; soybean meal, 44.6; Menhaden fish meal, 61.1 percent crude protein.

Table 2.—Daily gain and feed utilization: Effect of diet on growing lambs[1]

Diet (D)	corn(C)			corn + fish meal (FM)			corn + soybean meal (SBM)		
Criterion	None[2]	CL[3]	ZA[4]	None	CL	ZA	None	CL	ZA
No. of lambs	7	7	7	7	7	7	7	7	7
Daily gain, lb									
week 0-4	0.578	0.512	0.655	0.684	0.783	0.602	0.704	0.781	0.722
week 0-10	0.446	0.402	0.472	0.578	0.638	0.490	0.554	0.625	0.468
Daily feed, lb									
week 0-10	2.455	2.477	2.492	2.867	2.810	2.748	2.916	3.103	2.732
Gain/feed									
week 0-4	.291	.23	.302	.299	.324	.267	.306	.295	.299
week 0-10	.182	.156	.189	.199	.225	.179	.189	.200	.161

[1]Significant effects were detected ($P<.01$) as follows: Daily gain, week 0-4 and week 0-10; daily feed, week 0-10; SBM-FM vs C; gain/feed, week 0-4 and week 0-10; ZA vs CL-SBM-FM.
[2]No zeolite added.
[3]Clinoptilolite added at 2 percent of diet (see Table 1 for characterization of clinoptilolite).
[4]Zeolite NaA added at 2 percent of diet.

Table 3.—Kidney and liver weights: Effect of diet on growing lambs

Diet:	corn(C)			corn + fish meal (FM)[4]			corn + soybean meal (SBM)[4]			Significant contrasts
	None[1]	CL[2]	ZA[3]	None[1]	CL[2]	ZA[3]	None[1]	CL[2]	ZA[3]	
No. lambs	4	4	4	4	4	4	4	4	4	
Cold carcass wt, lb	54.0	50.5	51.8	58.4	57.6	53.4	57.8	50.9	58.0	
Cold carcass wt, pct of body wt	51.8	48.3	48.4	51.3	49.5	50.3	50.1	52.3	51.8	NS
Leg conformation score	13.3	13.7	13.3	13.5	13.8	13.3	13.8	12.8	13.8	NS
Kidney fat, pct	3.1	3.1	3.3	3.4	3.6	3.1	3.9	3.3	3.5	NS
Longissimus muscle area, in^2	4.2	3.7	4.0	4.0	4.2	4.2	4.2	3.9	4.0	NS
Carcass quality score	2.3	3.0	3.3	3.5	3.5	2.8	3.3	2.5	4.3	NS
Kidney wt, pct of body wt	.22	.21	.20	.23	.24	.22	.23	.27	.25	$P<.01$
Liver wt, pct of body wt	1.66	1.54	1.55	1.92	1.86	1.89	1.81	1.70	1.81	$P<.01$

[1]No zeolite added.
[2]Clinoptilolite added at 2 percent of diet (see Table 1 for characterization of clinoptilolite).
[3]Zeolite NaA added at 2 percent of diet.
[4]SBM = Soybean meal, FM = Fish meal.

Recommended Dietary Calcium and Zinc Levels Are Adequate for Growing Lambs

Wilson G. Pond[1]

Introduction

Limited information is available on optimum levels of dietary calcium (Ca) and zinc (Zn) and on Ca x Zn interactions in growing lambs. Zinc deficiency and toxicity have been described in growing lambs, and indications of Zn deficiency have been reported in reproducing ewes. Zinc requirements of ruminants appear to be related to composition of natural diets. The addition of low levels of chelated, or sequestered, Zn to purified diets for lambs appears to prevent Zn deficiency. High dietary Ca increases the dietary Zn requirement of swine; there is less evidence for such a relationship in ruminants, although there are reports of increased fecal excretion of manganese (Mn) and Zn in sheep fed a high Ca diet.

The present experiment was conducted to determine the effect of dietary Ca and Zn levels on body weight gain, feed utilization and blood and tissue traits of growing intact male and female lambs sired by Columbia or Suffolk rams.

Procedure

One hundred and sixty weanling Columbia- and Suffolk-sired crossbred lambs (about 8 weeks of age and 42 lb body weight) were randomly assigned within sex (80 rams and 80 ewes) to four diets involving two Ca (.5 pct, .8 pct) and two Zn (20 ppm, 100 ppm) levels with two pens of 10 lambs of each sex fed each diet. The composition of the diets is given in Table 1. Each replicate pen of 10 animals was kept in an 8 x 16 m pen with aluminum-painted expanded metal floors and provided with a metal self-feeder and an automatic float-regulated drinking bowl. Feed was offered in pelleted form *ad libitum*. Lambs were weighed on days 0, 21, 42, 63 and 84, and a blood sample was taken from four lambs (two randomly selected Suffolk-sired, except 1 and 3 lambs, respectively, in one pen) in each pen (total of 64 lambs) on days 0, 28, 56 and 84 for determination of hemoglobin, hematocrit and plasma Ca, P, Zn, protein, albumin and alkaline phosphatase concentrations. All of these are indices of Ca and Zn adequacy. Ca, P and Zn concentrations were determined in liver and bone ash and in plasma. After 84 days, four ram lambs from each treatment group were slaughtered and the right humerus (bone from forearm) and liver were removed for measurement of bone ash percentage and Zn concentration of the bone ash and dry liver. Remaining lambs were shorn (64 males, 80 females) and fleeces were weighed. Body weight, feed, wool and blood data were subjected to analyses of variance. Analyses of variance of feed intake and performance traits recognize the pen of lambs as the experimental unit. Each pen contained 10 lambs.

Results

The effects of level of dietary Ca and Zn on weight gain and feed consumption are summarized in Table 2. Males gained more weight during the 84-day feeding period than females (70.8 vs 56.1 lb), but there was no difference due to diet or to breed. Body weight gain and feed consumed were greater during the second half of the experiment than during the first half. Feed consumption was not significantly affected by diet, breed or sex.

Diet, breed or sex effects on hemoglobin levels and interactions with time were nonsignificant. Males fed the .5 percent Ca, 100 ppm Zn diet had reduced levels of hemoglobin compared with males fed other diets; whereas, in females, hemoglobin was not affected by diet. The biological importance of this sex x diet interaction is questionable because values for all lambs were within the normal range. Hematocrit declined with time ($P<.05$), but there were no interactions between diet, sex, breed and time. However, the magnitude of these time effects was probably not of biological importance because values for all lambs were within the range normally expected. Total plasma protein tended to decline from day 0 to 28 and then rise steadily from day 28 to 84 of the experiment in all diet groups.

There was an effect of diet and time, but not sex or breed, on the concentration of plasma Ca. Plasma P was unaffected by diet, sex, breed or time. Plasma Ca tended to decrease during the first 28 days and then rise at 56 days and plateau during the remainder of the experiment; lambs fed .8 percent Ca had higher plasma Ca than lambs fed .5 percent Ca ($P<.05$). Plasma Zn tended to decline during the first 28 days in the lambs fed diets unsupplemented with Zn, but plasma Zn concentration of lambs fed all four diets increased between days 28 and 56 and then declined at day 84 to a level lower than that on day 0. The biological significance of these statistically significant ($P<.01$) fluctuations in plasma Zn is unknown. If Zn were a limiting nutrient, a decline in feed consumption and plasma alkaline phosphatase in lambs not receiving supplemental Zn would be expected. While time effects were noted ($P<.01$), overall effects of diet, sex and breed on alkaline phosphatase were not significant.

There was no effect of diet or breed on growth of wool, but males grew more wool than females (3.12 vs 2.77 lb). Because lambs were not shorn before the experiment, shorn wool weights included pre- and post-treatment growth. Zinc concentration of dry liver was unaffected by diet (115, 123, 113 and 139 ppm for diets 1 through 4, respectively).

The similar performance of lambs fed diets containing .5 or .8 percent dietary Ca and 20 or 100 ppm dietary Zn indicates that the Zn requirement of the growing lamb is not increased by high dietary Ca, in contrast to the general observation in growing swine in which high Ca precipitates a Zn deficiency. The values for blood metabolites and for tissue Zn in this experiment confirm the lack of evidence of a Zn deficiency in lambs fed a high Ca diet. The slightly higher plasma Ca concentration of lambs fed a high Ca diet suggests that the recommended dietary Ca level of (Columbia- and Suffolk-sired crossbred) growing lambs may be marginal. However, supporting evidence for a marginal Ca deficiency is not provided by weight gain, feed consumption or changes in plasma P concentration. There was no diet by time interaction, suggesting that age did not have an effect on Ca or Zn requirement as measured by body weight gain, feed consumption or blood characteristics (except Zn). The similarity among treatment groups in percentage bone ash (57.9, 59.7, 57.9 and 58.8 pct for lambs fed diets 1 through 4, respectively) and in Zn concentration of bone ash (180, 197, 172, 224 ppm for lambs fed diets 1 through 4, respectively), however, supports the conclusion that the growing Suffolk- and Columbia-sired crossbred lamb raised in confinement on ungalvanized expanded metal floors from 8 to 20 weeks of age requires no more than .5 percent Ca and 19 to 26 ppm of Zn in the diet for normal growth and feed utilization. Furthermore, it is suggested that an elevated level of dietary Ca does not induce clinical signs of Zn deficiency in the growing lamb, in contrast to the general observations of this relationship in growing swine.

[1]Pond is the research leader, Nutrition Unit, MARC.

Table 1.—Composition of diets

Ingredient	Ca: .8 percent, Zn: 20 ppm (pct)	Ca: .8 percent, Zn: 100 ppm (pct)	Ca: .5 percent, Zn: 20 ppm (pct)	Ca: .5 percent, Zn: 100 ppm (pct)
Alfalfa hay[1]	19.1	19.1	19.1	19.1
Corn grain	71.35	70.35	72.25	71.25
Soybean meal, 44 percent CP	4.9	4.9	4.9	4.9
Limestone[2]	.9	.9	—	—
Zn oxide premix[3]	—	1.0	—	1.0
Iodized salt	.4	.4	.4	.4
Ammonium chloride	.5	.5	.5	.5
Durabond[4]	2.5	2.5	2.5	2.5
Monosodium phosphate	.3	.3	.3	.3
Vitamin A, D and E premix	.05	.05	.05	.05
Total	100.00	100.00	100.00	100.00
Analyzed composition				
Dry matter, pct	91.6	90.8	90.7	91.1
Protein (N x 6.25), pct	13.5	13.5	13.0	13.3
Cell walls (NDF), pct	19.6	19.2	19.7	21.7
Calcium, pct	.74	.88	.50	.49
Phosphorus, pct	.34	.38	.36	.35
Zinc, ppm	25.6	112.6	18.6	103.0
Ash, pct	5.7	6.1	5.0	4.9

[1]Sun-cured pellets.
[2]Fre-Flow #2 limestone.
[3]Provides 100 ppm ZnO (176 mg Zn)/lb diet; corn as a carrier.
[4]Lignin sulfonate (pellet binder), American Can Co., Chem. Products, Greenwich, CT 06830.

Table 2.—Effect of level of dietary calcium and zinc on weight gain and feed consumption of Suffolk- and Columbia-sired crossbred ram and ewe lambs

Item[1]	.8 percent Ca 20 ppm Zn: Male	.8 percent Ca 20 ppm Zn: Female	.8 percent Ca 100 ppm Zn: Male	.8 percent Ca 100 ppm Zn: Female	.5 percent Ca 20 ppm Zn: Male	.5 percent Ca 20 ppm Zn: Female	.5 percent Ca 100 ppm Zn: Male	.5 percent Ca 100 ppm Zn: Female
Weight gain, lb[2]	71.2	59.1	71.4	58.2	68.1	56.0	71.0	56.0
Daily gain, lb	.849	.703	.851	.692	.811	.666	.845	.666
Feed consumed, lb	301	339	329	282	354	300	335	310
Feed/gain	4.23	5.74	5.61	4.84	5.19	5.35	4.71	5.55

[1]Ten animals/pen, two pens/treatment.
[2]Weight gain of males was significantly greater than females ($P<.01$).

Effect of Level of Calcium and Rate of Reactivity of Calcitic Limestones on Performance of Producing Ewes

Mike H. Wallace, Wilson G. Pond and Kreg A. Leymaster[1]

Introduction

Calcium is an important nutrient to consider when evaluating ewe and lamb feeding programs. The last one-third of ewe gestation is particularly important to the developing fetus, with 75 percent of total fetal calcium deposited during this period. Furthermore, the amount of calcium secreted in milk by a ewe nursing two or more lambs is equivalent per unit body weight to the quantity of calcium secreted in milk by a high-producing dairy cow.

Calcium requirements for sheep (National Research Council [NRC], 1975) are based on the assumption that all supplementary sources of calcium have the same biological availability. However, biological availability of calcium can vary widely among supplementary calcium sources. For example, beef cattle calcium requirements are based on an assumption of 70 percent calcium availability (NRC, 1975); whereas dairy cattle calcium requirements are calculated assuming 45 percent calcium availability (NRC, 1978). The influence of calcium reactivity rate on calcium requirement and/or availability is unknown.

The addition of limestone buffer to corn silage/corn grain based diets for lactating dairy cows has been reported to improve overall nutrient utilization (Wheeler *et al.*, 1975; Wheeler, 1977). However, the literature shows considerable variability in animal response to limestone buffer additions. Wheeler *et al.* (1979) have indicated that differences in particle size and/or rate of reactivity among supplemental feed-grade limestone sources may explain some of the inconsistencies in animal response. The possible influence of limestone reactivity rate when fed in complete diets pre- and postpartum on ewe performance and lamb growth has not been investigated.

Corn silage production programs allow the harvesting of maximum quantities of nutrient energy per unit of fossil fuel required by the system. However, the use of corn silage based diets in sheep feeding programs has not been widely accepted. This lack of acceptance for corn silage-based diets by the sheep industry is due to a generally poorer performance by ewes fed corn silage-based diets when compared to ewes fed hay-crop silage-based diets. Part of this less than desirable performance by ewes fed corn silage-based diets could be associated with the considerable differences between corn silage and hay-crop silage in basic nutrient composition.

Little attention has been given in ruminant nutrition to examining the basic problems associated with corn silage-based diet formulations for sheep. While corn silage can be considered a high-energy forage, it is naturally low in both protein and calcium. Furthermore, a discrepancy exists between the 1968 and 1975 publications concerning the pre- and postpartum calcium requirements of ewes. For example, the 1975 publication is 18.4 and 10.0 percent lower in calcium requirements of ewes for the first 15 and last 6 weeks, respectively, of gestation than the 1968 published calcium requirements. On the other hand, calcium requirements for the first 8 weeks of lactation for ewes in the 1975 publication are 59.5 percent higher than those same requirements found in the 1968 publication. The potential long-term effect of these discrepancies in recommended levels of calcium for corn silage-based diets on both ewe and lamb performance has not been evaluated.

Procedure

Three-hundred twenty Hampshire x Suffolk, Coarse Wool, and Rambouillet ewes were assigned within breed and body weight to pens (20 head/pen) shortly after breeding in December 1979. Experimental diets (Table 1) consisting primarily of corn silage, hay, corn grain and supplement were randomly assigned to pens providing two replicates of the three calcitic limestones which differed in particle size and reactivity rate (Table 2), fed at the low level, and three replicates of each calcitic limestone, fed at the elevated level.

During the first 17 weeks, feed intake of rations in Table 1 was restricted to 3,400 kcal of digestible energy per head per day. Ewes were shorn and rations switched to the late gestation diets (Table 1) approximately four to six weeks prior to the start of lambing. Intake was restricted to provide 5,000 kcal of digestible energy per head per day. When lambing started, all animals were switched to the lactation rations (Table 1). During lactation all pens were fed *ad libitum,* which resulted in about 10 percent weighback each day and provided a minimum of 6,200 kcal digestible energy per head per day.

During lactation all lambs were fed *ad libitum* the standard pelleted creep diet (17.9 pct protein) consisting of 20 percent alfalfa, 80 percent concentrate. Consumption of creep feed was monitored.

All lambs were weaned at approximately 8 weeks of age and ewes were removed from treatment and grazed on bromegrass pasture during the maintenance period. In December 1980, ewes were again bred and individuals (plus sufficient replacements to provide 20 ewes per lot) placed back on the same respective diets utilized during the first year. The trial was then replicated the second year.

Results

Results of the two-year study are presented in Table 3. There were no significant ($P<.05$) differences or trends in the traits measured which were due to source of calcitic limestone or level of calcium in the rations.

The results of this trial indicate that, although calcium supplementation of corn silage-based rations for producing ewes is very important, the particle size of the limestone source did not affect performance traits, and the levels of calcium recommended by the NRC (1975) appear adequate for performance.

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[1]Wallace is the sheep operations manager; Pond is the research leader, Nutrition Unit; and Leymaster is a research geneticist, Genetics and Breeding Unit, MARC.

Table 1.—Experimental diets utilized

Item	First 17 weeks Gestation: Low Calcium	First 17 weeks Gestation: High Calcium	Last 4 to 6 weeks Gestation: Low Calcium	Last 4 to 6 weeks Gestation: High Calcium	Lactation: Low Calcium	Lactation: High Calcium
Ingredient[4]	pct					
Corn silage	35.0	34.0	50.0	49.0	50.0	47.0
Bromegrass hay[5]	35.0	35.0	20.0	20.0	10.0	10.0
Corn grain	22.95	23.15	18.7	18.7	22.8	24.9
Soybean meal (44 pct CP)	5.7	5.7	9.5	9.5	14.9	14.9
Limestone[123]	.3	1.1	0.5	1.5	.8	1.7
Monosodium phosphate	.3	.3	.5	.5	.7	.7
Elemental sulfur	.05	.05	.1	.1	.1	.1
Iodized salt	.5	.5	.5	.5	.5	.5
TM premix	.2	.2	.2	.2	.2	.2
Vitamin premix[6]	+	+	+	+	+	+
Chemical Analysis[7]	pct					
Crude protein	11.0	11.0	13.0	13.0	15.0	15.0
Calcium	.35	.70	.40	.80	.45	.90
Phosphorus	.35	.35	.40	.40	.45	.45
Digestible energy	66.8	66.8	68.2	68.2	72.0	72.0

[1]Alden limestone. (See Table 2).
[2]Fre-Flo #2 limestone. (See Table 2).
[3]H-White limestone. (See Table 2).
[4]Dry matter basis.
[5]Ground to 10 cm for feeding.
[6]Supplies 800 IU vitamin A, 80 IU vitamin D and 8 IU vitamin E per kg of diet dry matter.
[7]Calculated chemical analysis.

Table 2.—Particle size distribution, acid-consuming capacity, rate of reactivity and Rossett-Rice test of limestones

Type of Limestone	Particle size screen, um: 420	297	105	53	Pan	Acid-Consuming Capacity	T_{50} pH stat[4]	Rossett-Rice: Max pH	Lag time	Retention time
	pct of total					meq H^+/mole Ca + Mg	sec		min	min
Limestone[1]	44	36	16	0	4	1.92	4,110	2.01	31.4	NA[5]
Limestone[2]	2	6	58	2	32	2.20	1,230	2.88	2.8	NA[5]
Limestone[3]	0	0	6	8	86	2.19	60	5.53	2.4	41.2

[1]Alden limestone.
[2]Fre-Flo #2 limestone.
[3]H-White limestone.
[4]Rate of reactivity.
[5]pH did not exceed 3.0.

Table 3.—Effects of feeding three sources and two levels of limestone supplements to producing ewes

Limestone Source	Calcium Level	Birth Wt (lbs)	Standard Error	Lamb Vigor Score[4]	Standard Error	Lamb Pre-wean. ADG (lbs)	Standard Error	Ewe Lactational Weight Loss (lbs)	Standard Error	Pounds Lamb Weaned Per Ewe Lactating (lbs)	Standard Error	System Input/Output[5] (lbs)	Standard Error
Limestone[1]	High	11.2	±0.7	1.4	±0.2	.559	±.058	−0.8	±4.4	66.1	± 6.6	16.5	±1.7
	Low	11.7	±1.1	1.4	±0.2	.565	±.059	−2.0	±3.5	69.7	± 9.7	15.9	±1.9
Limestone[2]	High	11.1	±1.0	1.2	±0.1	.538	±.053	−7.7	±6.7	65.6	± 5.2	17.9	±2.1
	Low	11.1	±0.8	1.3	±0.3	.585	±.033	−3.2	±3.9	65.5	± 4.9	17.6	±1.3
Limestone[3]	High	11.9	±1.0	1.2	±0.2	.601	±.054	−3.2	±7.0	74.8	±10.7	17.0	±1.0
	Low	11.5	±1.1	1.2	±0.2	.589	±.033	−5.9	±4.2	67.8	± 6.3	17.5	±0.9

[1]Alden limestone.
[2]Fre-Flo #2 limestone.
[3]H-White limestone.
[4]Lamb vigor score determined shortly after birth; 1 = Strong, no assistance required; 2 = Weak, assistance given; 3 = Very weak, assistance required; 4 = Dead at birth.
[5]Input = Total feed consumed on an as fed basis and starting ewe weight; Output = Total pounds of lamb and wool produced and ending ewe weight.

Effects of Breed on Growth and Feed Efficiency of Ram Lambs

Cal L. Ferrell and Dave R. Notter[1]

Introduction

Breed differences in the efficiency of body weight gain over fixed age or weight intervals have been shown in cattle. These differences have been fairly predictable from mature size or degree of maturity of the breeds involved. In contrast, breed differences in efficiency of gain over similar maturity intervals have been much smaller and less dependent on mature size. Similar effects would be expected among breeds of sheep.

Effective use of breed differences requires knowledge of growth patterns and feed efficiency over a range of feeding levels and physiological intervals. Also, formulation of selection programs requires a knowledge of the amount of genetic variation in the efficiency of nutrient utilization independent of variation in mature size, degree of maturity and composition of the body and gain.

Procedure

Ram lambs (52 Rambouillet, 46 Dorset and 53 Finnsheep) were weaned at 50 days of age and fed free-choice in small pens. At 83 days of age (day 0), 14 lambs were slaughtered. The remaining lambs were fed once daily a pelleted diet (Table 1) at 100 (high; H), 85 (medium; M), or 70 percent (low; L) of free-choice intakes. Feed allowances were adjusted at two to three week intervals. Lambs were slaughtered at 35, 70, 105, 140 and 175 days after the initiation of the study (day 0). Variables measured for each lamb included cumulative feed intake, fleece-free empty body weight, body protein and fat weight and trimmed cut weight. Metabolizable energy (ME; feed energy available to the animal) requirements for maintenance (feed energy required for zero change in body energy) and gain were estimated for several physiological intervals (35 to 140 days, 48.5 to 83.8 lb, 12 to 26 percent fat, or 44 to 79 percent maturity) from the linear regression of ME intake (kcal/kg$^{.75}$) on body energy gain (kcal/kg$^{.75}$). Multiple regression of ME intake on energy gains in protein and fat was used to estimate ME requirements for energy gain as protein or fat.

Results

Breed x slaughter group means are shown in Table 2. Rambouillets and Dorsets were similar through 70 days, except that Dorsets had greater weights of trimmed cuts than Rambouillets. After 70 days, Rambouillets had more body protein and less body fat than Dorsets. Finns had less body weight, protein and trimmed cuts than the other breeds throughout the study, but were similar to the Rambouillets in body fat weight through 105 days and differed from Dorsets in body fat weights only after 70 days. Dorsets tended to have higher body fat percentages than Finns, and Finns tended to be fatter than Rambouillets.

Gross efficiencies of gains in body components (Table 3) indicated that breed differences in the efficiency of body weight gain were large during the weight interval, but small during all other intervals of measurement, and generally reflected differences in the proportion of fat in the gain. Larger breeds are usually also more efficient during a constant time interval; but, in this case, the much more rapid maturing rate of the Finn, coupled with the greater fat content and lower relative feed intake of the Dorsets, appears to have masked this relationship. No breed differences in gross energetic efficiency were observed, although Dorsets tended to be superior to Finns over time- and weight-constant intervals.

The efficiency of protein gain was similar for Rambouillets and Dorsets over fat and maturity intervals, but Rambouillets were more efficient than Dorsets over time and weight intervals. Rambouillets gained protein more efficiently than Finns over the weight interval, but tended to eat less and have a lower efficiency of protein gain over the maturity interval. The efficiency of protein gain was similar for Rambouillets and Finns over time and fat intervals. Dorsets gained body protein more efficiently than did Finns in the weight interval, but Finns were more efficient in age, fat, and maturity intervals. Finns consistently had the lowest efficiency of trimmed cut gains, reflecting differences in fat deposition patterns.

When ME intake was regressed on body energy gain, maintenance requirements (the amount of feed energy required to maintain constant body energy) were estimated to be 114 $\pm$ 9, 124 $\pm$ 14, 130 $\pm$ 13 and 130 $\pm$ 14 kcal/kg$^{.75}$/day for time, weight, fat and maturity intervals, respectively. The ME requirements for energy deposition (the slope of the regression lines) were 2.32 $\pm$ .17, 2.18 $\pm$ .19, 2.03 $\pm$ .18 and 2.04 $\pm$ .19 kcal/kcal body energy gain for time, weight, fat and maturity intervals, respectively. These values correspond to partial efficiencies of gain of 0.43, 0.46, 0.49 and 0.49 during these intervals. Breeds differed in ME intake at fixed body energy gains only during the time interval; Dorsets required 7 percent less ME than other breeds for equal body energy gains. Use of multiple regression techniques resulted in similar estimates of maintenance and indicated the ME requirements of energy gain as fat and protein to be 2.02 $\pm$ .36 and 3.90 $\pm$ 1.70 kcal/kcal, respectively. These values correspond to efficiencies of 0.49 and 0.26, respectively.

In summary, the ranking of these breeds for feed efficiency depended on both the interval (time, weight, fat or maturity) and the criterion (body weight, protein, energy or trimmed cuts) of evaluation. However, differences in efficiency over fat or maturity intervals were small, suggesting that variation in efficiencies among these breeds was small, when animals were evaluated at similar physiological states. These results indicate that breed differences in feed efficiency are generally small, if the breeds are evaluated over a similar degree of maturity interval. Dorsets appeared to have a somewhat greater propensity to fatten, a lower ability to retain protein at a fixed protein intake, and a lower maintenance requirement, but differences were small.

[1]Ferrell is a research animal scientist, Nutrition Unit, MARC; and Notter is an assistant professor, Department of Animal Science, Virginia State Polytechnic Institute and State University, Blacksburg.

Table 1.—Composition of the experimental diet

Component	Quantity (pct)
Ingredients:	
Dent yellow corn (IFN 4-02-931)	54.50
Soybean meal (IFN 5-04-604)	21.40
Sun-cured alfalfa hay (IFN 1-00-068)	19.40
Limestone (IFN 6-02-632)	1.10
Vitamin and mineral mixture[1]	.60
Ammonium chloride[2]	.50
Lignin sulfate	2.50
Compositional Analysis:	
Dry matter	88.90
Crude Protein[3,4]	20.50
Gross energy, cal/g DM[3]	4.42

[1]Contained (as percentage of the diet): salt, 0.39; S, 0.15; Se, 0.05; vitamins A-D-E, 0.01; trace mineral premix, 0.005.
[2]For prevention of urinary calculi.
[3]Average of 72 observations.
[4]Percentage of dry matter.

Table 2.—Effects on breed and slaughter group on cumulative feed intake, weights of body components, body energy content, body fat percentage and cumulative metabolic body weight[1]

Days on test	Breed	Cumulative feed intake, lb	Body weight, lb	Body energy content, Mcal	Body protein weight, lb	Body fat weight, lb	Trimmed cut weight, lb	Body fat, percent
0	Rambouillet	0	[4,5]40.3	39	[4,5]7.3	4.6	[3]. . .	10.2
	Dorset	0	[4]43.9	42	[4]7.7	5.3	[3]. . .	10.6
	Finn	0	[5]33.5	30	[5]6.0	3.5	[3]. . .	10.4
35	Rambouillet	84	[4]62.4	[4,5]65	[4]9.7	9.5	[4]19.8	14.9
	Dorset	84	[4]63.7	[4]69	[4]9.9	10.1	[4]21.8	15.7
	Finn	77	[5]52.9	[5]54	[5]8.2	7.7	[5]16.8	14.4
70	Rambouillet	[4,5]179	[4]77.4	89	[4]12.6	13.2	[4]26.5	[4]17.1
	Dorset	[4]194	[4]79.4	96	[4]12.6	15.2	[5]29.1	[4]19.2
	Finn	[5]168	[5]64.8	87	[5]10.6	14.1	[6]22.5	[5]21.7
105	Rambouillet	[4]300	[4]89.5	[4,5]122	[4]15.2	[4]19.6	[4]31.5	[4]21.6
	Dorset	[4]304	[4]89.9	[4]136	[5]14.1	[5]23.4	[4]31.5	[5]25.9
	Finn	[5]262	[5]77.2	[5]112	[6]12.6	[4]18.7	[5]25.6	[4,5]23.8
140	Rambouillet	[4]430	[4]101.0	[4]160	[4]15.9	[4]28.2	[4]34.8	[4]27.6
	Dorset	[4]430	[4]101.0	[5]174	[5]14.6	[5]32.4	[4]35.9	[5]32.1
	Finn	[5]379	[5]86.0	[6]143	[6]13.2	[6]25.6	[5]29.3	[4]29.3
175	Rambouillet	[4]489	[4]108.2	[4]171	[4]16.3	[4]30.4	[4]37.5	[4]27.7
	Dorset	[4]494	[4]107.4	[4]183	[5]15.2	[5]34.0	[4]38.6	[5]31.0
	Finn	[5]454	[5]92.2	[5]152	[6]13.4	[6]27.6	[5]32.2	[4,5]29.6
Average[2]	Rambouillet	[4]249	[4]82.7	[4]109	[4]13.4	[4]17.6	[4]28.2	[4]20.3
	Dorset	[4]254	[4]83.3	[5]119	[5]12.8	[5]20.3	[5]29.5	[5]23.2
	Finn	[5]223	[5]70.3	[6]99	[6]11.2	[4]16.5	[6]23.6	[5]22.3

[1]Averaged over 100 (H), 85 (M) and 70 (L) percent of *ad libitum*. H only at 0 days on test; M and L only at 175 days on test.
[2]Averages for days 35 through 140 only.
[3]. . . Trimmed cut weights were not measured at day 0.
[4,5,6]Means within a column and at the same days on test with different superscripts differ ($P<.05$).

Table 3.—Gross efficiency of gains of empty body components over four intervals

Interval	Breed	Gain/lb feed for: Body weight, lb	Body energy, Mcal	Body protein, lb	Trimmed cuts, lb
35 to 140 days	Rambouillet	.125	.278	[1].0177	.0471
	Dorset	.117	.301	[2].0119	.0431
	Finn	121	.279	[1].0166	.0416
48.5-83.8 lb	Rambouillet	[1].172	.288	[1,2].0262	[1].0680
	Dorset	[1].161	.313	[1].0224	[2].0576
	Finn	[2].133	.293	[2].0183	[3].0446
12-26 percent fat	Rambouillet	.139	.283	.0197	.0522
	Dorset	.147	.309	.0196	.0526
	Finn	.148	.306	.0213	.0486
44-70 percent mature	Rambouillet	.152	.288	[1,2].0211	.0582
	Dorset	.153	.312	[1].0208	.0547
	Finn	.164	.318	[2].0247	.0530

[1,2,3]Means within a column and interval with different superscripts differ.

Effects of Breed and Intake Level on Allometric Growth Patterns in Ram Lambs

Cal L. Ferrell and Dave R. Notter[1]

Introduction

The level of feed intake affects body composition at a constant age in swine, sheep and cattle, but the effects of intake level on body composition at constant weight are not clear. Data are available that show increased, decreased or no change in fatness of sheep or pigs when fed at differing levels of intake to a constant weight. That breed differences in body composition at a fixed age or weight exist among cattle or sheep has been demonstrated. Further, an inverse relationship between mature weight and maturing rate has been shown such that large breeds tend to be less fat than small breeds at the same age or weight. The objectives of this study were to evaluate breed differences in body composition at points of similar physiological maturity and effects of intake level on body composition.

Procedure

Rambouillet (52), Dorset (46) and Finnsheep (53) ram lambs were used. Within each breed, rams were serially slaughtered at random every 35 days between about 48 days (weaning) and 258 days of age. Rams in the first two groups were slaughtered at weaning or after having been fed *ad libitum* for 35 days postweaning. Rams in the last five groups were individually fed at 100, 85 or 70 percent of *ad libitum* intake for 35 to 175 days before slaughter. Fourteen rams were also killed at about 223 days of age after being fed at maintenance for 105 days. A shorn, shrunk slaughter weight was taken immediately before slaughter. Weights of kidney, pelvic and heart (KPH) fat, blood, head and feet, pelt, vital organs (kidneys, heart, liver, spleen and lungs) and empty gastrointestinal (GI) tract and hot carcass weight were recorded. Carcass backfat and body wall thickness and loin eye area were measured 24 hours postmortem. The wholesale leg, loin, rack and boneless shoulder from the right side of the carcass was trimmed to 1/4 in external fat and weighed as trimmed cuts. Composition (protein, water and fat) of the offal and carcass were determined and results were combined to give the composition of the body.

The allometric equation (Model 1; $Y = aW^{\beta}$) was used to describe relationships between weight of body components (Y) and total body weight for 63 rams (22 Rambouillet, 19 Dorset and 22 Finn) fed *ad libitum*. The use of this equation assumes that growth of body parts is proportional to a power (β) of body weight. Values of β greater than, equal to or less than 1.0 indicate relative growth rate of a body part is faster than, equal to or slower than the relative growth rate of the whole body. Specifically, the allometric growth coefficient (β) is defined as the ratio of the relative growth rate of a component to the relative growth rate of the body and is estimated as the constant β in the above equation. That β varies linearly with weight rather than being a constant was tested by the equation (Model 2) $Y = aW^{\beta}e^{cw}$. In this case, the estimate of β is $\beta + C^{w}$. Results of this model are presented only if β was found to vary with weight.

Results

Body components may be segregated into groups on the basis of the value of the allometric growth coefficient (β, Table 1). The groups were 1) body components that grow at rates approximately equal to body growth rate ($.9<\beta>1.1$) such as carcass, offal, gastrointestinal tract and trimmed cuts; 2) body components that grow moderately faster than the total body such as body wall thickness ($\beta = 1.17$); 3) body components that grow considerably faster than the total body ($\beta > 1.17$) such as body fat, backfat thickness and KPH fat; and 4) body components that grow slower than the total body ($\beta < .9$) such as body water, body protein, vital organs and loin eye area. These results show that developmental growth in sheep is characterized by different growth rates of body components, with few growing at the same relative rate as the whole body.

Growth coefficients of some body components varied with body weight (Model 2, Table 1). Growth coefficients increased with body weight for body fat, KPH fat and gastrointestinal tract and decreased with weight for body water, vital organs and trimmed cuts. These results argue against the concept that growth coefficients are constant throughout growth. Instead, growth was characterized by changes in the relative growth rates of many body parts.

The growth coefficient for trimmed cuts decreased from 1.19 at 66 lb to 0.87 at 99 lb and was equal to 1.0 at 85 lb. Thus, at 85 lb, weight of trimmed cuts ceased to increase in relation to body weight and began to decline. Maximum yield of trimmed cuts was at 89.7 lb for Rambouillet, 89.3 lb for Dorset and 76.5 lb for Finn rams. Larger breeds maintained a more favorable pattern of trimmed cut yield through heavier weights than did smaller breeds.

Growth coefficients were different for the different breeds of sheep for several components (Table 2). Finn rams gained carcass weight less rapidly and offal weight more rapidly than Dorset rams. Rambouillet rams were intermediate. This result was partially the result of the faster relative growth rate of KPH fat and gastrointestinal tract, which were components of the offal, in Finn rams as compared to the other breeds. That growth coefficients were affected more by weight (value of C was lower) in Finn rams than in Rambouillet rams may reflect a more rapid maturing rate of the Finn rams.

The effects of feeding level on weights of body components at the same body weight are shown in Table 3. Lambs fed at all restricted levels had greater carcass weights, trimmed cut weights and loin eye areas but less total offal than rams of the same weight that had been fed *ad libitum*. Rams fed at 85 and 70 percent of *ad libitum* had more body water and less body fat, KPH fat and body wall thickness than rams fed *ad libitum*. However, rams fed at maintenance for an extended period of time had less body water and vital organs, but more backfat thickness and body wall thickness than rams fed *ad libitum* to the same weight. These results show differential effects of feed restriction depending on the degree of restriction. Lambs fed at levels that allowed some growth were in general leaner than those fed *ad libitum* to equal weights, but when young rams were held at constant weight, the maturation process (characterized by fattening) appears to take precedence over the growth process (characterized by protein deposition).

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[1]Ferrell is a research animal scientist, Nutrition Unit, MARC; and Notter is an assistant professor of animal science, Virginia Polytechnic Institute and State University, Blacksburg.

Table 1.—Allometric growth coefficients relating body component measures to body weight for rams fed *ad libitum*

	Growth coefficients[1]		
	Model 1	Model 2	
Component	β	β	C
Carcass weight	1.05		
Offal weight	.93		
Body water	.79	1.10	−.013
Body fat	1.97	1.44	.022
Body protein	.89		
Kidney, pelvic and heart fat	2.17	1.48	.029
Vital organs	.72	1.13	−.017
G.I. tract	1.04	.60	.018
Trimmed cuts	1.04	1.85	−.022
Backfat thickness	2.59		
Body wall thickness	1.17		
Loin eye area	.89		

[1]See text for description of models. Coefficient of 1.00 indicates component grew at same rate as total body weight. Coefficients of less than 1 indicate slower growth rates and values greater than 1, faster growth rates than total body weight.

Table 2.—Breed specific growth coefficients relating body component measures to body weight for rams fed *ad libitum*[1]

	Model 1			Model 2					
Component	Rambouillet	Dorset	Finn	Rambouillet		Dorset		Finn	
	β	β	β	β	C	β	C	β	C
Carcass weight	1.06	1.07	1.03						
Offal weight	.93	.90	.96						
Body water	.81	.77	.79	1.07	−.010	1.21	−.017	1.07	−.017
Kidney, pelvic and heart fat	2.02	2.17	2.31	2.13	−.002	.42	.070	.67	.075
Vital organs	.75	.67	.72	.92	−.007	1.51	−.033	1.24	−.024
G.I. tract	.91	1.06	1.16	.57	.014	.381	.33	.17	.046

[1]See text for description of models. Coefficient of 1.00 indicates component that grew at the same rate as body weight. Values less than 1 indicate rates slower growth rates and values greater than 1, faster growth rates than total body weight.

Table 3.—Percentage difference in weight of body components of rams fed at restricted levels compared to those fed *ad libitum*[1]

	Intake level		
Component	85 pct *ad libitum*	70 pct *ad libitum*	Maintenance
Carcass weight	1.8	2.3	2.7
Offal weight	−2.0	−3.4	−3.9
Body water	2.4	1.5	−8.1
Body fat	−3.3	−1.2	32.2
Body protein	−1.7	0.0	2.0
Kidney, pelvic and heart fat	−14.3	−16.7	−25.0
Vital organs	0.0	−5.6	−23.5
G.I. tract	−4.7	0.0	9.4
Trimmed cuts	4.8	4.9	10.6
Backfat thickness	−9.7	−9.4	10.5
Body wall thickness	−0.6	−7.4	6.9
Loin eye area	3.2	4.0	4.5

[1]Calculated as 100 (restricted—*ad libitum*)/*ad libitum*.

Feedlot Performance and Metabolism Parameters of Lambs Fed Vomitoxin-Contaminated Hard Red Winter Wheat

Robert R. Oltjen, Mike H. Wallace, Benjamin Doupnik, Jr., Terry J. Klopfenstein and Vince H. Varel[1]

Introduction

Wheat scab or headblight is caused primarily by *Fusarium graminearum* (*Gibberella zeae*) or other closely related fungal species on wheat and other small grains. Presence of the fungus on harvested wheat is indicated by white (tombstone) and pink discolored kernels. Under normal late spring/early summer climatic conditions, the incidence of wheat scab in the Central Great Plains is usually very low. However, when exceptionally cool and wet conditions persist during May and June, wheat scab can become widespread as it did in Nebraska in 1982.

F. graminearum can produce one or more of the trichothecene mycotoxins which have been associated with vomiting and feed refusal in non-ruminant animals. Vomitoxin or deoxynival enol (DON) is the most commonly reported naturally occurring trichothecene. Levels as low as 0.1 to 0.2 ppm DON have been shown to cause a vomiting response with orally dosed swine, whereas feed refusal is observed ony at higher levels.

It has been reported that *F. graminearum* infected corn did not affect the performance of lactating dairy cattle; however, content of specific mycotoxins were not reported. In another report, feed containing 250 ppm DON in cattle diets resulted in 60 percent feed refusal. The natural occurrence of DON in grain harvested from scab-infected fields, however, would be expected to be much lower than 250 ppm. There have been very few feeding studies carried out with ruminants fed naturally occurring levels of DON.

The present study was conducted to evaluate the influence of scab-damaged hard red wheat on the feedlot performance and metabolic parameters of growing lambs.

Procedure

Fifty half-Finn, quarter-Dorset, quarter-Rambouillet ram lambs born in May and weighing approximately 60 lb wer randomly paired and then alloted to 25-4 ft x 6 ft raised slatted floor pens. Lambs (10) in each of five pens were fed *ad libitum* one of five diets shown in Table 1 for 70 days. The scab-damaged wheat contained 8 ppm vomitoxin. The same source of wheat was used for both the feedlot and metabolism trials. The diets averaged 88.5 percent dry matter, 14.5 percent crude protein, 0.9 percent Ca, and 0.4 percent P. The lambs were weighed on two consecutive days at the start and end of the trial and at biweekly intervals during the trial. The lambs were observed daily for vomitoxin-induced symptoms including vomiting, fecal scouring or any other abnormal behavior or illness.

One lamb from each of the replicate pairs assigned to diets 2 through 5 (20 lambs total) was individually penned in a metabolism crate and maintained on the same respective diet utilized during the 70-day feeding trial. Lambs were allowed to adapt to their new surroundings and feed intake was adjusted prior to the 5-day collection period. Ruminal contents were collected at slaughter from lambs fed diets 2 and 5 and were analyzed for several ruminal parameters.

Results

Vomitoxin-contaminated wheat (8 ppm) was fed to achieve three dietary concentrations: low (1.7 ppm), medium (3.5 ppm), and high (5.2 ppm). The high concentration did not appear to depress feed intake (Table 2) of the lambs. It did result in somewhat lowered gains and feed efficiency compared to lambs fed the corn or wheat control diets. During the first 28 days of the study, the lambs fed the highest concentration of vomitoxin wheat had the lowest feed intake and daily gains; however, after this "adaptation period," the lambs responded well, and there were no significant differences ($P>.05$) for any of the measured production parameters during the 70-day study. Performance of lambs fed the control corn vs control wheat diets was consistent with previously reported data.

Since there were slight differences observed in the feedlot trial, a metabolism trial was conducted to determine if these differences were related to feed intake or digestibility and utilization of nutrient components of scab-infected vs normal wheat. Analyses of ruminal fluid samples were also conducted since vomitoxin activity may alter ruminal parameters. The corn control diet was omitted because of the lack of differences in the feedlot trial.

The apparent dry matter digestibility of the low vomitoxin wheat diet was higher ($P<.05$) than was that of the high vomitoxin diet (Table 3). The high vomitoxin diet contained a higher concentration of indigestible lignin (4.2 pct) compared to the low vomitoxin diet (2.7 pct), and the difference may have occurred because of this factor. Visual observation of the scab-damaged wheat indicated smaller and lighter grains which contained higher fiber and lignin portions than the control wheat.

None of the remaining parameters measured in the metabolism-ruminal fluid trial were different due to treatment (Table 3). The nitrogen balance data seem to favor the contaminated wheat over the control wheat; however, the amount of variation was very large, and thus the means did not differ significantly. Like wise, analysis of ruminal fluid indicated very similar values, indicating that fermentation had not been altered by the presence of vomitoxin in the wheat.

The results from these studies indicate that scab-damaged wheat containing 8 ppm vomitoxin can be safely fed up to 65 percent of the total diet to lambs without adversely affecting animal performance.

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Table 1.—Percentage composition of experimental diets

Ingredient	Corn Control	Wheat Control	Vomitoxin Wheat		
			Low	Medium	High
Diet No.	1	2	3	4	5
Normal Hard Red Winter Wheat, rolled	—	65.0	43.3	21.7	—
Corn, rolled	58.0	—	—	—	—
Scab Hard Red Winter Wheat[1], rolled	—	—	21.7	43.3	65.0
Alfalfa, (dehy. ground)	27.5	27.5	27.5	27.5	27.5
Soybean Meal	7.0	—	—	—	—
Liquid Molasses	5.0	5.0	5.0	5.0	5.0
Salt (T.M.)	0.5	0.5	0.5	0.5	0.5
Limestone	1.0	1.0	1.0	1.0	1.0
Steamed Bone Meal	0.5	0.5	0.5	0.5	0.5
Ammonium Chloride	0.5	0.5	0.5	0.5	0.5
Vitamin A and D[2]	+	+	+	+	+
Rumensin[3]	+	+	+	+	+

[1]Contained 8 ppm vomitoxin.
[2]Vitamin A and D supplement was fed to provide 2,000 I.U. Vitamin A and 200 I.U. Vitamin D per lb of diet.
[3]Rumensin added as coccidiostat to provide 9 gram of monensin/ton of diet.

Table 2.—Feedlot performance of lambs fed differing levels of scab-infected wheat (70 days)

Diet	Corn Control	Wheat Control	Vomitoxin Wheat			Standard Error
			Low	Medium	High	
Diet No.	1	2	3	4	5	
No. lambs/treatment	10	10	10	10	10	
Initial weight, lb	64	65	65	59	71	
Daily feed intake, lb	3.45	3.36	3.35	3.01	3.44	0.11
Daily gain, lb	0.64	0.62	0.58	0.54	0.56	0.04
Feed/gain ratio	5.52	5.45	5.85	5.69	6.22	0.28

Table 3.—Apparent digestion, nitrogen balance and ruminal parameters of lambs fed differing levels of scab-infected wheat

Diet	Wheat Control	Vomitoxin Wheat			Standard Error
		Low	Medium	High	
Diet No.	2	3	4	5	
No. lambs	5	5	5	5	
Metabolism results:					
Apparent digestion coefficients, pct					
Dry Matter	[12]76.4	[1]78.9	[12]75.2	[2]74.4	0.96
Crude Protein	78.5	80.7	76.9	76.4	1.25
Nitrogen Retention					
Percent of Intake	4.4	17.1	13.5	10.1	4.31
Percent of Digested	5.8	21.4	17.5	13.1	5.42
Ruminal Parameters					
pH	5.8	—	—	5.9	0.27
Bacterial count $X10^{10}$/ml	2.4	—	—	2.8	0.06
Votatile fatty acids, molar pct					
Acetic	55.4	—	—	55.2	5.76
Propionic	25.0	—	—	27.3	5.92
Isobutyric	1.3	—	—	1.6	0.09
Butyric	11.1	—	—	13.6	2.97
Isovaleric	2.4	—	—	1.1	0.41
Valeric	3.5	—	—	2.5	0.76

[12]Means with different superscripts on the same line are significantly different (P<.05).

Intake and Selectivity by Grazing Sheep

Hans-Joachim G. Jung, Ahmed E. Sidahmed, Ling-Jung Koong and James G. Morris[1]

Introduction

It is a well-established fact that sheep are very selective in their grazing behavior. Sheep consume a diet on pasture which is consistently higher in quality than the pasture forage overall. This is apparently due to the preference sheep exhibit for leaves over stems, and green versus non-green forage. But, while we know sheep are selective grazers, we have very little information on the magnitude of their selectivity or whether selectivity changes in response to changing pasture conditions. The data reported here represent a partial summary of the first two years' results from a long-term study on the response of sheep to changing pasture conditions.

Procedure

A smooth bromegrass pasture was divided into four 3-acre experimental pastures using electric fencing. In 1982 the pastures were stocked with 4 or 6 lambs/acre, with two replicates of each stocking rate. The lambs were Finn and Finnsheep cross yearling wethers with an initial weight of 98.3 ± 2.9 lb. In 1983 the same pastures were stocked with 6 or 12 Finnsheep cross wether lambs, initial weight of 62.4 ± 1.9 lb. In both years the lambs grazed the experimental pastures continuously from early May through August. Quantity and quality of available forage was determined periodically by clipping all standing forage in thirty, one ft^2 plots in each pasture.

Esophageal fistulation of sheep was used for collection of diet samples. These animals were maintained on smooth bromegrass pasture near a barn to provide shelter and attention in order to maintain the fistulated animals in good health. Periodically the fistulated sheep were taken to the experimental pastures for diet collections. The fistulated animals were fasted overnight and then allowed to graze in the experimental pastures the following morning. Samples were collected in plastic bags placed over the esophageal fistula. The animals were allowed to graze normally after the collection was completed.

All forage and diet samples were dried and ground prior to analysis. *In vitro* dry matter digestibility (IVDMD), crude protein content (CP) and cell wall content (CW) were determined for all samples. The magnitude of selectivity exhibited by the sheep was estimated as a ratio of diet to forage:

$$\text{Selectivity Ratio} = \frac{\text{diet IVDMD, CP or CW}}{\text{forage IVDMD, CP or CW}}$$

If sheep are not selective in their grazing behavior, the selectivity ratio (SR) will equal 1.00, whereas, if the SR becomes greater than 1.00, the animals are selecting for the quality component. A SR of less than 1.00 indicates that the sheep are selecting against the forage constituent.

Results

The available forage present under both stocking rates in 1982 and 1983 are given in Figure 1. The difference in available forage between 1982 and 1983 when both were stocked with equivalent numbers of sheep (6hd/acre) is due to 3 causes. First, weather conditions were not the same in both years; second, in 1982 the lambs were heavier initially and therefore had a greater energy requirement; and third, in 1983 the pastures were fertilized with 80 lb nitrogen/acre which increased their productivity. The major point to be derived from the data in Figure 1 is that the different stocking rates caused substantial differences in available forage in both years. Surprisingly, while quantity of available forage varied dramatically with stocking rate, forage quality did not differ significantly due to stocking rate in either year. Quality of the forage declined with time in both years with IVDMD decreasing from 77.4 percent to only 40.1 percent, CP declined from 13.9 percent to 4.0 percent, and CW increased from 49.1 percent to 75.1 percent.

While available forage was different between stocking rates, diet quality followed the same trend as forage quality (i.e. stocking rate had no effect). Diet IVDMD declined from 76.7 percent to 43.7 percent, CP declined from 21.2 percent to 8.4 percent, and CW of the diet increased from 46.6 percent to 64.2 percent during the course of the summers. The sheep were selective for IVDMD (SR = 1.12 and 1.32), and CP (SR = 1.91 and 2.44), and selected against CW (SR = .85 and .85) in both 1982 and 1983. This degree of selectivity was not unexpected. Of more interest is the relationship of SR for IVDMD and CP with the overall forage quality at the time the diet samples were collected. For IVDMD, the SR was essentially 1.00 at very high forage IVDMD (i.e. −72 pct) and increased slowly until forage IVDMD fell below 60 percent (Fig. 2). At this point the sheep increased the intensity of their selection dramatically as forage quality declined. Although available forage was different between the two years of this work, both years produced the same general pattern for the relationship of SR with forage quality. There is an indication in the data from 1983 that when IVDMD of the available forage became very low (less than about 44 pct), selectivity by the sheep declined. The response for CP selectivity was very similar (Fig. 3). When forage CP exceeded about 9 percent the SR ratio remained constant; however, unlike selectivity for IVDMD, the SR for CP always remained high (1.50). This indicates the sheep always selected a diet containing more CP than present in the total available forage. At forage CP levels below 9 percent the SR increased dramatically in both years. Again, the 1983 data suggest that, under extremely poor forage quality conditions (less than about 5 pct CP), SR declines. Although the SR for CW of the diet always remained below 1.00, no discernible trend with forage CW content was observed. The significance of these data is that they indicate strongly that sheep will alter the degree of diet selectivity they exhibit in response to changes in quality of available forage. Also, this selectivity appears to be independent of the quantity of available forage. It is theorized that sheep must expend much greater amounts of energy to find and consume a high quality diet under pasture conditions with low forage availability than under high forage availability, if both pastures are of equal quality. Experiments are underway to document this theory. An increased understanding of the relationship of diet selectivity, total forage consumed, and energy costs of selective grazing in response to changing pasture conditions will allow development of more efficient management models for grazing systems.

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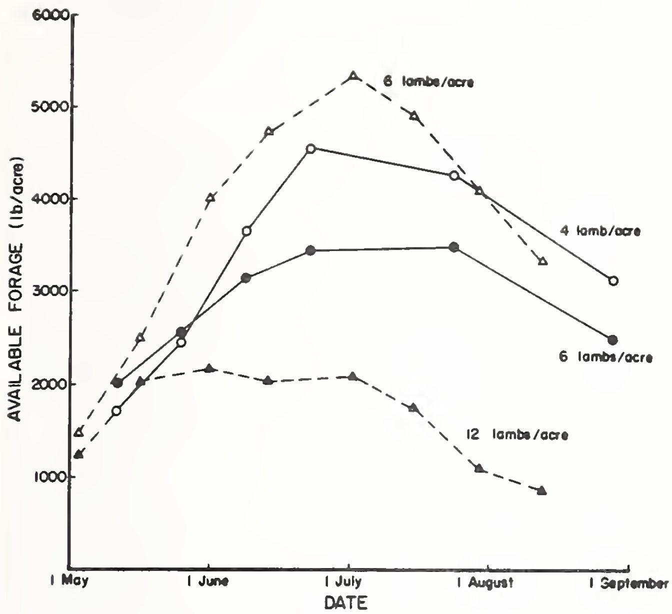

Figure 1—Changes in available forage during the grazing seasons in 1982 (— — —) and 1983 (— — —) at various stocking rates of lambs.

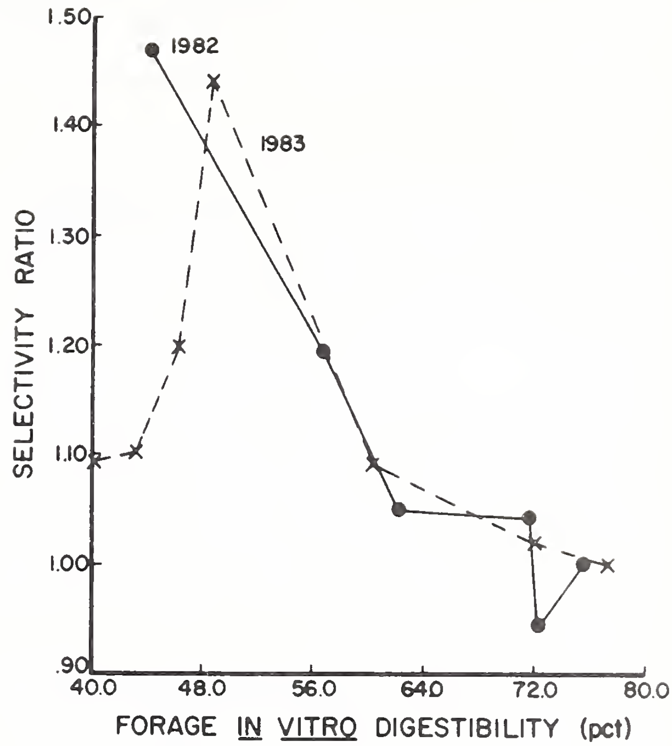

Figure 2—The relationship between selectivity ratio of sheep diets and *in vitro* digestibility of the available forage.

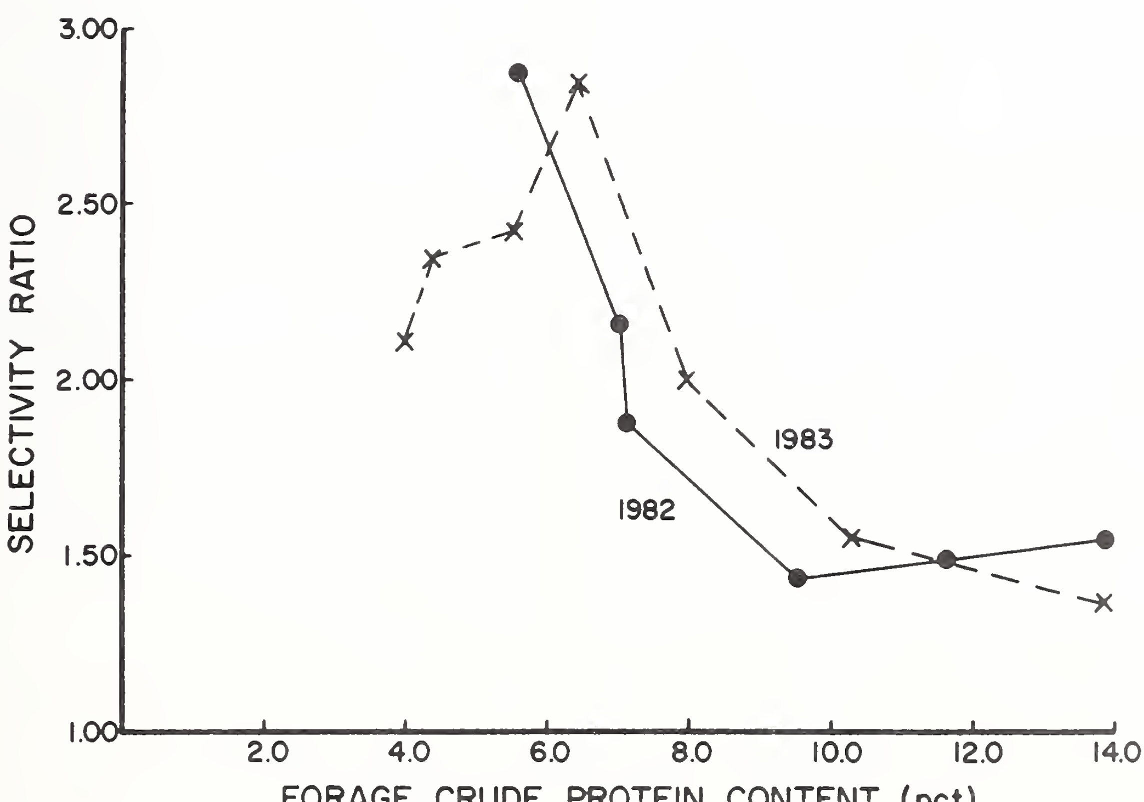

Figure 3—The relationship between selectivity ratio of sheep diets and crude protein content of the available forage.

Feedlot and Carcass Characteristics of Lambs Produced Under Varying Levels of Management Intensiveness

Tom G. Jenkins[1]

Introduction

Market lamb production may be increased by increasing the level of management intensiveness. Traditional management practices for finishing market lambs may not be suitable for production systems where producers employ designed mating systems (e.g., crossbreeding or composites) to effectively use differences among sheep breeds in conjunction with increased frequency of lambing (annual vs. accelerated). The decision to increase ewe productivity through accelerated lambing changes conventional management practices with regard to age of weaning and the season in which market lambs would be fed to market weight. This may lead to indecision with regard to the appropriate management practices for finishing the lambs. The present study was designed to evaluate differences in feedlot performance and carcass characteristics of crossbred lambs that were produced under three different production systems.

Procedure

Finn-cross ewes were mated to either Suffolk or Columbia rams within each of the management systems described in Table 1. Ewe lambs from each of these defined sheep production systems were sampled at weaning. After a 21- to 28-day adjustment period, the lambs were assigned to small pens (6-10 head/pen) for feeding. The lambs were fed free choice pelleted complete rations (80 pct concentrate, 20 pct alfalfa) until the average pen weight was approximately 100 to 110 lb. Individual weights were recorded every two weeks and feed intake was recorded on a pen basis. Lambs were slaughtered at a commercial slaughter facility after the feeding period. Carcass weights and carcass cooler data were recorded at the time of slaughter. The means (averages) from the replicated pens within management system for the annual systems were analyzed. Within the accelerated system, replicated pen means for each of the lambing periods were analyzed.

Results

As described in Table 1, the ewe lambs were produced in three management systems varying in management intensiveness. Within the High systems, lambs were born during January-February (AC1), May (AC2) or September (AC3). Lambs produced in the Medium management system were born in March (AN1) and lambs produced in the Low management system were born in May (AN2). As indicated in Table 1, lambs produced in the High management system (accelerated lambing) were weaned at approximately 6 to 7 weeks of age and after 10 weeks of age in the two annual systems. Mean ages at the start of the feeding trials were 78, 75 and 70 days for AC1, AC2 and AC3 lambs, 124 days for AN1 and approximately 91 days for AN2 (birth date was not recorded for individual lambs of the AN2 group).

Feedlot performance and carcass characteristics are presented in Table 2. Lambs produced under the High system were younger and lighter starting on test than lambs from the two annual production systems. Within the High system, lambs from the May lambing season (AC2) were younger and lighter on test than were lambs from the AC1 and AC3 groups. Lambs produced in the two annual management systems tended to be heavier at slaughter than lambs from the High management system. These differences in slaughter weight may be attributed to time available for slaughter at a commercial slaughter facility. For this reason, growth, feed intake and carcass characteristics were adjusted to a constant liveweight at slaughter.

Lambs produced in the Medium (AN1) system had the lowest average daily gain (ADG), consumed the least total amount of feed to attain the desired weight but were the least efficient in converting feed to liveweight (Table 2). Low system lambs (AN2) had a greater ADG and consumed more total feed to attain slaughter weight than AN1 but produced more liveweight per pound of feed consumed than the AN1 lambs. As would be expected, lambs from the AC1, AC2 and AC3 groups tended to consume the greatest amount of feed to reach the desired slaughter weight. This is directly attributable to the management practice of weaning at an early age and transferring the lambs directly into a feedlot. The postweaning ADG and feed efficiency of lambs from AC1, AC2 and AC3 groups exceeded that of AN1 lambs and was equal to that of AN2 lambs.

Differences in carcass characteristics were observed both among management systems and within the High management system. Lambs produced in the High management system tended to be fatter and have more desirable leg conformations and carcass quality scores than did lambs produced in the Medium management system. The degree of fatness attained by the AC1 group resulted in the smallest percentage retail cuts, and lambs from the AN2 group exhibited the largest percentage retail cuts. No differences were observed among the management groups for hot carcass weight.

Results from this study indicate the management decisions regarding lambing frequency and level of resource input during the preweaning period have a pronounced effect on postweaning feedlot performance and carcass characteristics. If accelerated lambing programs are to be successfully adopted into the industry, weaning at an early age would likely be required. This creates a problem with regard to the management of the early weaned lambs. The present study indicates that the postweaning ADG and feed efficiency are adequate for early weaned lambs. However, the length of time required to attain desirable slaughter weight results in an extremely large quantity of feed consumed, which may not be economically feasible. Both groups of lambs from the annual lambing groups required less feed for finishing with the lambs from the AN1 group, requiring approximately 115 lb less per animal fed even though the feed efficiency was the poorest for this group. More information is required for postweaning management of early weaned lambs.

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[1]Jenkins is a research animal scientist, Production Systems Unit, MARC.

Table 1.—Management criteria for high, medium and low sheep production systems

Item	High	Medium	Low
Lambing program	Ewes exposed to lamb three times in 2 years. Exogenous hormones used prior to spring breeding. Rams used in spring breeding phototreated.	Annual	Annual
Breeding	Individual sire mating.	Multisire group matings.	Multisire group matings.
Lambing facilities	Raised slatted floor lambing barn with jug pens (approximately 15 sq ft of slatted floor space/ewe).	Open front poleshed with jug pens (approximately 18 sq ft/ewe).	Open front poleshed and pasture, no jugs (approximately 10 sq ft barn and 1.4 acres/ewe).
Preweaning	Ewes and lambs fed *ad lib.* Lactation period done in slatted floor facilities (approximately 15 sq ft/ewe).	Ewes and lambs in drylot until about 30 days postpartum, then maintained on pasture (approximately 0.4 acres/ewe).	Lambs and ewes maintained on pasture (approximately 0.9 acres/ewe).
Weaning	Lambs weaned at approximately 6 weeks of age.	Lambs weaned at 10 weeks of age or later.	Lambs weaned at 10 weeks of age or later.
Artificial rearing	Intensive use. Weak lambs or lambs with litter size greater than twins transferred to nursery.	Weak lambs or lambs from litter size greater than twins transferred to nursery.	Not available.
Labor	High commitment, all phases.	High commitment during lambing.	Low commitment, all phases.

Table 2.—Mean feedlot performance and carcass characteristics of lambs produced from three management systems[1]

	Production System				
	High			Medium	Low
Trait	AC1	AC2	AC3	AN1	AN2
Weight on test	^{1}53	^{2}57	^{1}57	^{3}90	^{4}62
Weight at slaughter (lb)	^{1}115	^{2}96	^{3}106	^{2}110	^{1}103
Average daily gain (lb/day)	^{1}0.64	^{1}0.57	^{1}0.57	^{3}0.48	^{1}0.58
Average feed consumed (lb)	^{1}280	^{2}237	^{2}242	^{3}145	^{4}211
Feed efficiency[5]	0.20	^{1}0.20	^{1}0.21	^{2}0.13	^{1}0.20
Dressing percent	47.8	57.3	50.0	50.0	53.4
Carcass weight (lb)	55	55	53	55	55
Backfat (in)	^{1}0.35	^{1}0.36	^{3}0.28	^{2}0.31	^{3}0.25
Estimated kidney fat (pct)	^{1}4.5	^{2}4.9	^{2}6.6	^{2}5.2	^{2}4.7
Leg conformation[6]	^{1}12.6	^{1}12.3	^{2}12.9	^{3}11.9	^{1}12.5
Carcass quality[6]	^{12}12.4	^{234}11.8	^{1}12.9	^{4}11.4	^{123}12.0
Percent retail cuts	^{12}80	^{12}80	^{3}78	^{1}79	^{2}81
Number of pens	10	8	6	12	12

[1234]Superscripts differing within trait indicate significant differences.
[5]Pounds of gain divided by pounds of feed consumed.
[6]P° = 14, P− = 13, C+ = 12, C° = 11 (P = Prime, C = Choice).

Seasonality of Estrous Activity in Several Breeds and Breed Crosses of Sheep

Ronald K. Christenson, Tom G. Jenkins and J. Joe Ford[1]

Introduction

A short gestation period and the availability of prolific breeds of sheep are two advantages that make the sheep a highly productive ruminant. However, one disadvantage is the seasonal breeding characteristic of sheep. In countries with temperate climates, reproductive activity of sheep is restricted to certain months of the year. Decrease in daylength is the primary factor controlling the onset of estrous activity in ewes.

Using different breed combinations because of greater estrous activity during different times of the year has been suggested for year-round market lamb production. Several reports have examined the seasonal variation of estrous activity throughout one to two years; however, the number of breeds and breed crosses examined has been limited.

The objective of the following two experiments was to determine estrous activity of several breeds and breed crosses of sheep at different times of the year. Upon determining estrous activity of several breeds, management decisions regarding optimum breeding seasons for accelerated lambing programs and the breed composition for lamb production throughout most of the year can be more easily established.

Procedure

Experiment I. Six hundred thirty-one ewes (crossbred ewes representing Finnsheep and Rambouillet sires crossed with Suffolk, Hampshire, Dorset, Rambouillet, Targhee, Corriedale and Coarse Wool ewes and straightbred ewes representing Suffolk, Hampshire, Dorset, Rambouillet, Targhee, Corriedale and Coarse Wool) were lambed in February and March. In addition, 84 contemporary ewes that did not lamb were included in the study. The number of animals in each breed and breed cross is shown in Table 1.

Finnsheep and Rambouillet crossbred ewes were exposed during lactation to vasectomized crossbred Finnsheep rams fitted with harnesses and marking crayons for the period of March 20 to April 10. Tup (estrous or breeding) marks were recorded daily. Ewes were maintained in drylot and fed a corn silage-based ration *ad libitum* throughout lactation.

Lambs were weaned on April 27, and all crossbred and straightbred ewes were grouped and moved to a brome pasture. Fourteen vasectomized crossbred Finnsheep rams were placed with the ewes; tup marks were recorded twice weekly from April 28 to May 18, June 12 to July 2 and July 28 to September 28. Vasectomized rams remained with the ewes from April 28 to September 28 and were fitted with harnesses and marking crayons during the periods of estrous monitoring. Beginning July 28, as ewes exhibited estrus, they were removed from the main flock to facilitate recording tup marks and to allow the ewes to be assigned to subsequent experiments. Ewes with tup marks observed between July 28 and September 28 were grouped into three periods: Period I, July 28 to August 17; Period II, August 18 to September 7; and Period III, September 8 to September 28.

Experiment II. Crossbred Finnsheep (half-Finnsheep x quarter-Dorset x quarter-Rambouillet, produced by the reciprocal mating of Finnsheep x Dorset and Finnsheep x Rambouillet) and Morlam ewes (composite formed in the 1960's by mating Merino, Dorset Horn, Targhee and Columbia-Southdale ewes to Rambouillet rams) were monitored for estrous activity during 2 years. Twenty-five ewes of each breed type/year were housed under drylot conditions. These ewes were allowed to remain nonpregnant during the investigation period. Age (1 to 5 yr) structure of the two breed-type flocks was similar. Adequate nutrition was provided to ensure that nutritional constraints upon estrous activity were not imposed.

Results

Experiment I. Estrus was observed in 5.4 percent of the Rambouillet and Finnsheep crossbred ewes during lactation (March 20 to April 10). The incidence of estrus after lactation (April 28 to May 18) was 1.1 percent in the Rambouillet and Finnsheep crossbred and straightbred ewes. During summer (June 12 to July 2), the incidence of estrus increased slightly to 5.2 percent for all ewes, and the expression of estrus did not differ for straightbred, Rambouillet or Finnsheep crossbred ewes (5.9, 5.7 and 4.1 pct).

The incidence of estrus during Period I (July 28 to August 17), presented in Table 2, was greater than that observed from June 12 to July 2. Forty-two percent of all ewes showed estrus during Period I. Both breed of dam and breed of sire had a significant influence on the occurrence of a late-summer estrus.

In Period I, straightbred Rambouillet, Targhee, Dorset and all Rambouillet-sired crossbred ewes, except Rambouillet x Hampshire and Rambouillet x Suffolk crosses, had the greatest estrous activity. Corriedale, Coarse Wool, Rambouillet x Hampshire, Rambouillet x Suffolk, Finnsheep x Rambouillet and Finnsheep x Targhee were intermediate in estrous activity. Straightbred Suffolk and Hampshire and all remaining Finnsheep-sired crossbred ewes had the lowest estrous activity during Period I. Thus, 40 to 70 percent of Rambouillet-sired crossbred ewes can be expected to show estrus during the first half of August and could provide the genetic stock for an early lambing group. Finnsheep x Rambouillet and Finnsheep x Targhee crossbred ewes were nonsignificantly greater in estrous activity when compared to Finnsheep x Dorset crossbred ewes, even though Dorset and Rambouillet x Dorset were similar in estrous activity as compared to straightbred Rambouillet, Targhee and crossbred Rambouillet x Targhee ewes. Therefore, it appears that crossbred ewes of different Finnsheep-sired breed combinations respond differently in estrous activity during early August. After combining breeds of dam, Rambouillet crossbred ewes had a greater incidence of estrus in Period I than straightbred ewes, and straightbred ewes had a greater incidence than Finnsheep crossbred ewes (Table 3).

At the end of Period II, Finnsheep crossbred and straightbred ewes had a more similar accumulated percentage (71 pct) of ewes showing estrus, but the difference between these two groups and Rambouillet crossbred ewes (84 pct) still existed. At the end of Period III (September 28), no significant difference was observed in incidence of estrus between the Rambouillet and Finnsheep crossbred ewes; however, Rambouillet crossbred ewes maintained an advantage over straightbred ewes.

Experiment II. Percentage of ewes exhibiting estrous activity by breed type and month pooled over the 2-year study are represented in Figure 1. The percentage of Finnsheep-cross and Morlam ewes exhibiting estrous activity did not differ significantly from each other during the breeding season (December, January, September and October), nor were significant differences noted during the anestrous period (June and July). Estrous activity was significantly different for Morlam ewes versus Finnsheep-cross ewes for the remaining months. A greater number of Morlam ewes expressed estrus during August than did Finnsheep-cross ewes (15 vs 2, respectively). During the months of February, March, April and May, the

breed-type ranking was reversed with significantly more Finnsheep-cross ewes exhibiting estrus than Morlam (45 vs 35, 43 vs 30, 33 vs 15 and 23 vs 4 ewes, respectively).

Lamb production efficiency can be increased by several management systems such as multiple lambings per year, introduction of prolific breeds of sheep to existing flocks, and/or repeated lambings throughout most of the year using different genetic stock for breeding at different times of the year. These combined studies indicate that the majority of Rambouillet-sired crossbred ewes show estrous activity during August. Next, most straightbreds and crossbred ewes show estrous activity from mid-September through January. As has been shown in other research studies after January, estrous activity begins to decline in certain straightbreds; however, in straightbred Finnsheep and in crossbred Finnsheep, estrous activity continues through to March and April. Therefore, lambs may be produced routinely from January through September, and intensive lambing and rearing facilities can be used throughout the year.

[1]Christenson is a research physiologist, Reproduction Unit; Ford is the research leader, Reproduction Unit; and Jenkins is a research animal scientist, Production Systems Unit, MARC.

Table 1.—Number of ewes per experimental breed group

	Breed of Sire		
Breed of Dam	Straightbred	Rambouillet	Finnsheep
Suffolk	32	21	26
Hampshire	46	[1]25	35
Rambouillet	51	[2]51	40
Dorset	39	[3]36	34
Targhee	41	33	44
Corriedale	26	32	43
Coarse Wool	35	30	46

[1]This subgroup included ewes with parentage of Hampshire x Rambouillet and the reciprocal cross.
[2]These ewes are also listed as straightbred Rambouillet.
[3]This subgroup included ewes with parentage of Dorset x Rambouillet and the reciprocal cross.

Table 2.—Breed of dam and sire effects on estrous activity in straightbred and crossbred ewes during Period I (July 28-August 17)

	Breed of Sire		
Breed of Dam	Straightbred	Rambouillet	Finnsheep
Suffolk	$^{1}7.9 \pm 8.2$	$^{2}37.3 \pm 10.2$	$^{1}8.6 \pm 9.3$
Hampshire	$^{3}17.4 \pm 6.9$	$^{4}44.9 \pm 9.6$	$^{3}10.7 \pm 8.1$
Dorset	$^{3}59.0 \pm 7.5$	$^{3}68.0 \pm 7.7$	$^{4}22.8 \pm 8.1$
Rambouillet	$^{3}74.0 \pm 6.8$	----	$^{4}42.3 \pm 7.4$
Targhee	$^{34}55.6 \pm 7.3$	$^{3}66.3 \pm 8.2$	$^{4}40.5 \pm 7.3$
Corriedale	$^{3}42.5 \pm 9.0$	$^{3}64.8 \pm 8.4$	$^{4}9.7 \pm 7.4$
Coarse Wool	$^{3}49.3 \pm 7.9$	$^{3}53.1 \pm 8.7$	$^{4}21.0 \pm 7.2$

[12]Means ± SEM without common superscripts differ significantly ($P<0.05$).
[34]Means ± SEM without common superscripts differ significantly ($P<0.01$).

Table 3.—Estrous activity in straightbred and crossbred ewes by periods[1]

	Breed of Sire		
	Straightbred	Rambouillet	Finnsheep
No. of ewes	270	177	268
I. July 28-August 17	$^{2}43.7 \pm 3.3$	$^{3}59.1 \pm 4.3$	$^{4}22.2 \pm 3.8$
II. August 18-September 7	$^{2}71.1 \pm 2.8$	$^{3}83.8 \pm 3.6$	$^{2}71.6 \pm 3.1$
III. September 8-28	$^{2}78.1 \pm 2.4$	$^{3}87.4 \pm 3.1$	$^{23}81.9 \pm 2.7$

[1]Percent ewes exhibiting first estrus was cumulative for periods.
[234]Means ± SEM in the same row without common superscripts differ significantly ($P<0.01$).

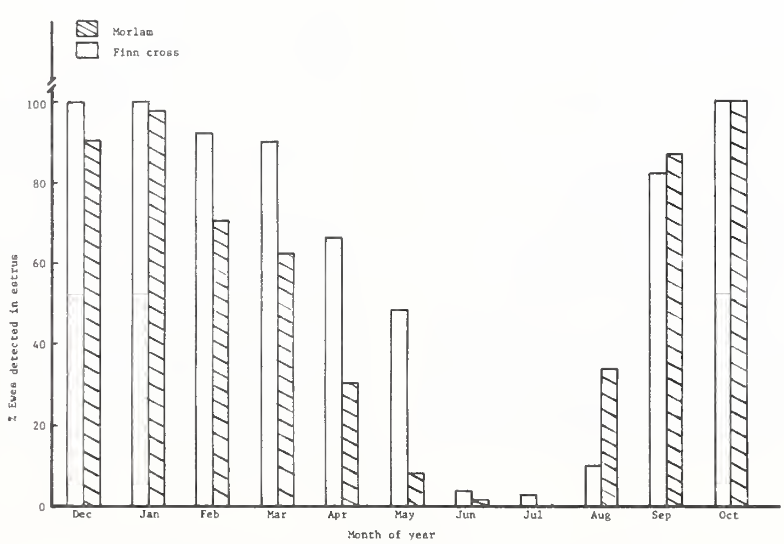

Figure 1. Estrous activity by months for Morlam and Finnsheep-cross ewes.

Seasonality of Reproductive Function in the Domestic Ram

Bruce D. Schanbacher[1]

Introduction

Only recently have factors which control reproductive activity in rams been studied. From these studies, it has become apparent that the problems of subfertility often observed in controlled breeding programs, particularly those involving out-of-season breeding, are not confined to the ewe, but involve the ram as well. Several of these studies have pointed out the important relationship between decreasing photoperiod or "short days" and enhanced reproductive activity in rams. In summary, sexual activity, testicle size and reproductive hormone levels in the blood all peak in autumn when daylengths are decreasing. Thus, the breeding season for both rams and ewes coincides in the autumn. Enhanced reproductive function at other times of the year has been assessed in this "short-day" breeder by exposure to environments with controlled photoperiod.

Procedure

Mature rams have been maintained in either light-control buildings or environmentally controlled facilities to monitor and assess reproductive parameters in response to short daylengths during the nonbreeding season. All rams had previous breeding experience and were of proven fertility. Maintenance diets consisted of corn silage and/or alfalfa hay. Testicle size was determined by caliper measurements and reproductive hormone profiles determined from venipuncture samples or more intensive sequential sampling regimens. In some studies, fertility assessments have been made by joining rams (controls and light-treated) with untreated or progestin-synchronized PMSG-treated ewes. PMSG-treated females have been used in ram fertility assessments because this treatment insures ovulation and optimum fertility of the ewe and permits more precise assessment of the sire.

Results

Responses in testes diameter (Fig. 1) and mean serum concentrations of luteinizing hormone (LH) and testosterone (Fig. 2) are illustrated for Dorset, Finnsheep, Rambouillet and Suffolk rams exposed to alternating 12-week periods of short (8L:16D) and long (16L:8D) photoperiods. Rams entered this study (week 0) during early spring when daylength was increasing. These rams were housed in individual pens in a temperature-controlled facility (59-64°F) so as not to confound the influences of photoperiod (i.e., daylength) on testicular and reproductive-endocrine function. Testicular and endocrine responses of these rams were significantly affected by both breed and photoperiod. In all four breeds, testes diameter increased during short days and decreased during long days. Peak in testes diameter following short days occurred 3 to 4 weeks later in Suffolk rams relative to the other three breeds and suggests that 12 weeks may not be long enough to realize maximum testicular growth for Suffolk rams. Changes in testicle size are positively associated with changes in reproductive-endocrine function. Increases in serum LH were observed early after exposure to short daylengths, whereas serum testosterone levels were elevated later such that highest concentrations coincided with the time of maximal testes diameter.

The results of this study confirm the findings of previous reports and show that cycles in reproductive activity in rams can be entrained to artificial lighting schedules. The longitudinal changes in testis diameter and reproductive-endocrine secretion are consistent with the hypothesis that sheep respond inversely to daylength. Although photoperiod effects were most prominent in this study, breed differences were evident. Collectively, the above findings suggest that subtle breed differences exist in photoperiod-induced seasonality of reproduction and that more detailed assessment of breed-fertility interactions are warranted.

In another study at the Roman L. Hruska U.S. Meat Animal Research Center, ten mature Suffolk rams were assigned to one of two groups and exposed starting in late February to ambient conditions of temperature and photoperiod (control rams, $n = 5$) or to ambient temperature and short daylengths (8L:16D) in a closed building with artificial lighting. Rams were exposed to either natural or short daylengths for ten weeks before fertility assessment and for an additional three weeks during breeding to PMSG-treated ewes in May. Scrotal circumference was monitored at weekly intervals during the first ten weeks of treatment to determine the consequences of short daylengths on testicle size. Figure 3 shows that testes size was comparable for control and light-treated rams when the experiment began. However, after the third week, scrotal circumference measurements of short-day treated rams began to increase, whereas scrotal circumference of control rams continued to decrease. Semen evaluation of control and short-day treated rams immediately prior to breeding showed little difference in the percentage of live sperm and percentage of sperm with normal morphology (excluding acrosomal criteria) but sperm numbers, percentage of sperm with progressive motility, and the percentage of sperm with normal acrosomes were greater in samples from treated rams when compared to control rams.

Behavioral assessment of PMSG-treated ewes suggested that nearly all ewes showed estrus in response to progestogen-PMSG treatment (Table 1); however, only 67 percent of ewes exposed to control rams were mated as compared to 89 percent of ewes exposed to short-day treated rams. More importantly, however, 67 percent of ewes exposed to treated rams lambed; whereas only 32 percent of ewes exposed to control rams lambed (Table 1). This difference in lambing percentage was highly significant. The number of lambs born per ewe lambing favored joinings with short-day treated rams, but this difference did not reach significance.

Results of this second study confirm our previous conclusions that short daylengths are beneficial to reproductive performance in rams and add substantially to our understanding of seasonal influences on ram fertility. In summary, it appears that the average ram is a poor breeder during the nonbreeding season and that exposure to artificial photoperiods comprised of short days can induce the full sequence of events necessary to maximize breeding efficiency of the ram. Short-day rams are inherently more active than rams exposed to long days and prove more useful as breeders during the nonbreeding season. Experimental work is underway at MARC that might alleviate the need for light-control facilities and yet maintain sexual activity and optimum fertility of rams for year-round use.

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[1]Schanbacher is a research physiologist, Reproduction Unit, MARC.

Table 1.—Lambing results for ewes mated to rams which were exposed to natural or artificially shortened daylengths[1]

Treatment	Estrous activity	Mating activity	Lambing rate	No. lambs born per ewe lambing	Actual no. lambs born
	pct				
Control rams[2] (natural photoperiod)	95.4 ± 2.3	66.7 ± 18.1	32.0 ± .05	1.72 ± .14	81
Rams on short-days[2] (8:16 photoperiod)	98.0 ± 1.3	89.3 ± 2.9	[3]67.2 ± .05	1.95 ± .12	202

[1]Means (±SEM) for five animals.
[2]Control rams were maintained out-of-doors under natural lighting conditions of spring, whereas rams on short days were maintained in a closed building under controlled lighting (8 h light and 16 h darkness for 91 days). Each ram was exposed to 30 progestogen-PMSG synchronized ewes.
[3]P<.01. Significantly different from control rams.

From B. D. Schanbacher, J. Anim. Sci. 49:927-932, 1979.

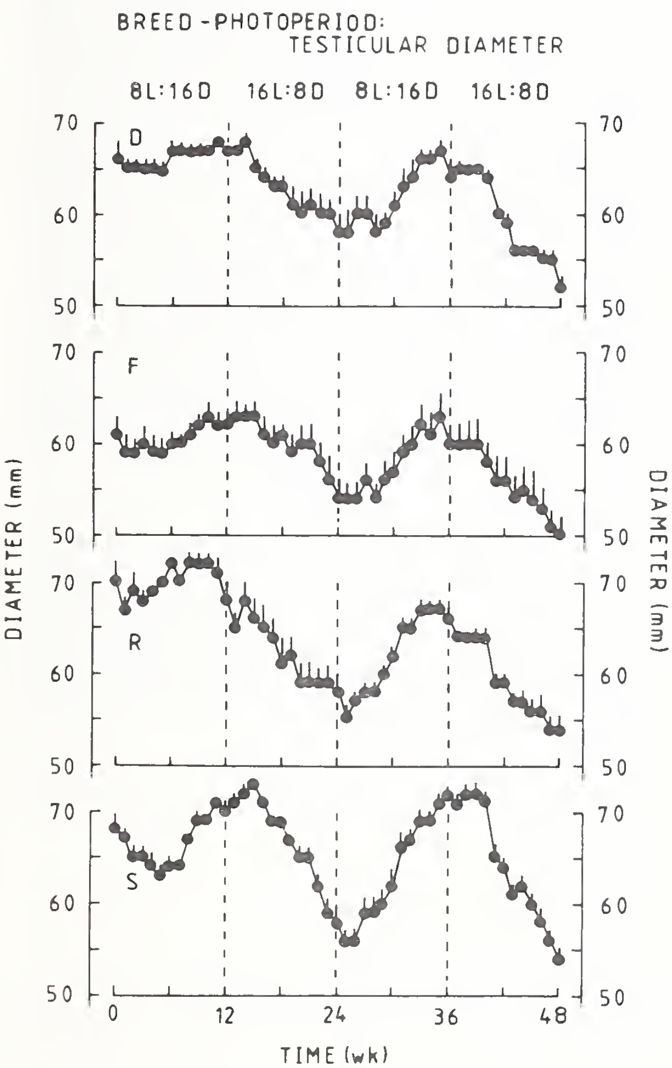

Figure 1—Longitudinal changes in testes diameter in Dorset (D), Finnsheep (F), Rambouillet (R) and Suffolk (S) rams exposed to contrasting short (8L:16D) and long (16L:8D) photoperiods. Means (±SE) for five rams of each breed. (From M. J. D'Occhio, B. D. Schanbacher and J. E. Kinder, Biol. Reprod. 30:1039-1054, 1984).

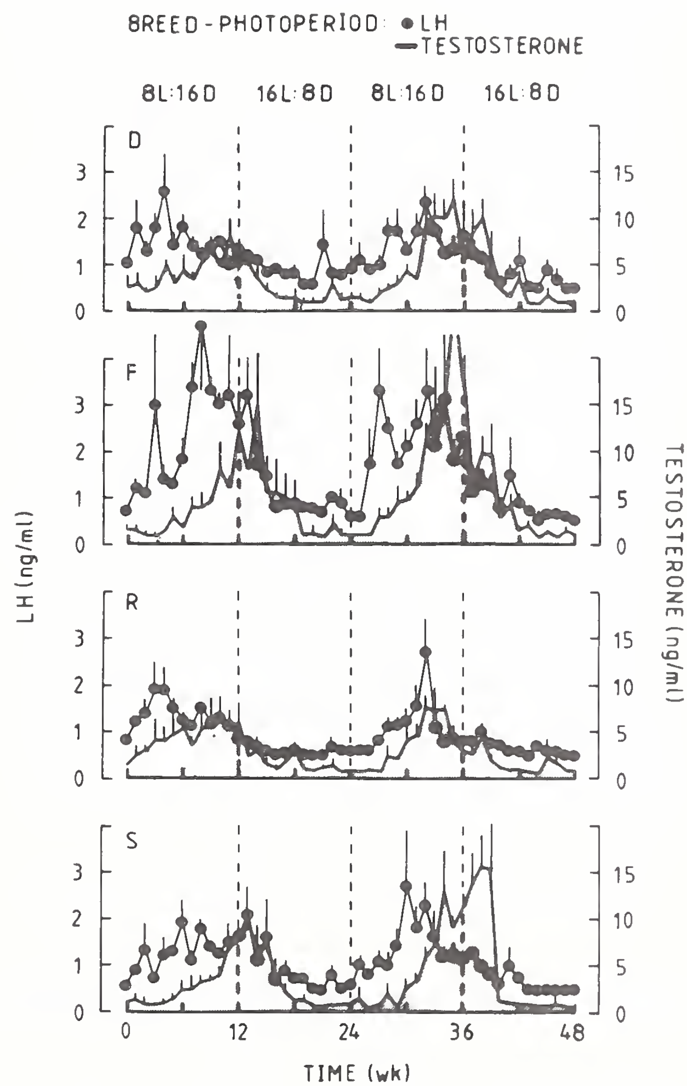

Figure 2—Longitudinal changes in serum LH and testosterone concentrations in Dorset (D), Finnsheep (F), Rambouillet (R) and Suffolk (S) rams exposed to contrasting short (8L:16D) and long (16L:8D) photoperiods. (From M. J. D'Occhio, B. D. Schanbacher and J. E. Kinder, Biol. Reprod. 30:1039-1054, 1984).

Photoperiodic Influences on Growth and Performance of Lambs

Bruce D. Schanbacher[1]

Introduction

Body weight gain and feed intake of lambs are regulated in part by environmental temperature and photoperiod (Schanbacher, Hahn and Nienaber, 1982). Because photoperiod (daylength) can be easily manipulated in lamb confinement facilities, we have investigated the effects of artificial lighting schedules on growth and performance of ram, wether and ewe lambs. The results of three studies are summarized below. The first two of these compare long days (16-h photoperiod; 16L(light):8D(dark)) with short days (8-h photoperiod; 8L:16D) in rams and wethers (study 1) and ewes (study 2). In the third study, the effects of a split photoperiod (7L:9D:1L:7D) comprising a one-hour light flash within a short 8-h day are reported.

Procedure

Twenty-four crossbred ram lambs and 24 crossbred wether lambs at 10 weeks of age and weighing 52 lb were caged in pairs and housed in a controlled environment. In this study and subsequent trials, temperature was maintained near 65°F and relative humidity fluctuated between 25 and 35 percent. Lambs in this and subsequent trials were fed *ad libitum* a pelleted diet consisting of 60 percent ground shelled corn, 20 percent alfalfa hay, 15 percent soybean meal and 5 percent vitamin-mineral supplement. Body weight gain and feed consumption were recorded, and lambs were slaughtered at 22 weeks of age when market weights averaged 120 lb. Carcass traits were recorded from which quality and yield grades were determined.

In study 2, 72 crossbred ewe lambs at 12 weeks of age and weighing 46 lb were randomly assigned to one of six treatment groups. Treatments were of a 2x3 factorial design consisting of two photoperiods (16L:8D and 8L:16D) and three constantly imposed temperatures (46°F, 65°F, and 88°F). Ewe lambs were fed and managed similar to the rams and wethers of study 1 except that ewe lambs were slaughtered at 26 weeks of age when market weights averaged 100 lb.

To determine whether variations in 16-h of continuous light might enhance lamb growth and performance equal to that of a 16L:8D photoperiod schedule, a third study investigated the effects of a split photoperiod comprising a one-h light flash 16 h after subjective dawn. In this study, 72 crossbred ram lambs were randomly assigned to one of three treatment groups and managed as lambs in the previous studies. Lambs were either exposed to a 16L:8D, 8L:16D or 7L:9D:1L:7D photoperiod.

Results

Because the effect of sex and photoperiod on growth and performance of growing-finishing lambs was evident in this study, photoperiodic effects are shown separately for rams and wethers in Table 1. These data show that rams grew more rapidly and efficiently than wethers and that long days promoted more rapid gains and improved feed efficiency when compared to short days. These differences were associated with increased feed consumption during the 12-week study (i.e., the average ram exposed to 16L:8D consumed 327 lb of feed, whereas the 8L:16D ram, 16L:8D wether and 8L:16D wether consumed only 288, 301, and 267 lb of of feed, respectively).

Photoperiod and/or temperature affected all characteristics studied except for the carcass attributes of percentage kidney-pelvic fat, backfat thickness and USDA quality and yield grade. An interaction between photoperiod and temperature was observed only for feed intake. The effects of contrasting photoperiod-temperature environments on performance and carcass traits are shown in Table 2. Growth rates of ewe lambs were greatest under long days and cool (46°F) or normal ambient (65°F) temperatures. Like short days, elevated ambient temperature is a detriment to feed intake and rapid weight gain. Similar to that observed with rams and wethers, long days improved average daily gain, conversion of feed to liveweight gain, final weight and carcass weight.

The superior growth rate, feed efficiency and carcass yields observed in these studies with rams, wethers and ewes exposed to 16L:8D photoperiods provide incentive for producers to impose long daylengths on market lambs housed in facilities where artificial lighting is used. Increased carcass weight without sacrifice of quality or yield is a distinct advantage which should more than offset the costs associated with supplemental lighting. Several biological functions are temporally coupled with photoperiod rhythmicity, including growth rate.

The results of the third investigation are shown in Table 3 and confirm that equivalent performance can be achieved in ram lambs by exposing them to a split photoschedule comprised of a one-h light flash positioned 16 h after subjective dawn. Importantly, this stimulatory photoperiod (in terms of growth enhancement) consists of only 8 h of light per day. This finding not only allows for minimal supplemental lighting in a confinement operation but also provides insight into the physiological mechanisms and bio-rhythms which are important for efficient livestock production.

[1]Schanbacher is a research physiologist, Reproduction Unit, MARC.

Table 1.—Means (± SE) for performance and carcass traits of growing-finishing lambs (study 1)

Treatment	Average daily gain, lb/d	Feed efficiency, lb feed/ lb gain	Final wt, lb	Carcass wt, lb	Backfat thickness, in	Kidney-pelvic fat, pct	Quality grade[1]	Yield grade[2]
Rams:								
16L:8D	.90 ± .03	4.3 ± .1	129 ± 2.6	70 ± 1.3	.21 ± .03	2.8 ± .3	10.6 ± .3	1.4 ± .2
8L:16D	.75 ± .03	4.5 ± .1	117 ± 2.5	62 ± 1.3	.20 ± .02	2.6 ± .2	10.8 ± .2	1.3 ± .2
Wethers:								
16L:8D	.76 ± .03	4.6 ± .1	117 ± 2.6	65 ± 1.3	.27 ± .02	3.2 ± .2	11.2 ± .2	1.8 ± .2
8L:16D	.66 ± .03	4.8 ± .1	109 ± 2.5	60 ± 1.3	.24 ± .03	3.2 ± .3	11.4 ± .2	1.6 ± .2

[1]Quality grade: 10 = low choice, 11 = average choice and 12 = high choice.
[2]Yield: 1 = high cutability; 5 = low cutability.

From Schanbacher and Crouse, J. Anim. Sci. 51:943-948, 1980.

Table 2.—Means (± SE) for performance and carcass traits of growing-finishing ewe lambs (study 2)

Treatment	Average daily gain, lb/d	Feed efficiency, lb feed/ lb gain	Final wt, lb	Carcass wt, lb	Backfat thickness, in	Kidney-pelvic fat, pct	Quality grade[1]	Yield grade[2]
Ewes:								
16L:8D, 46 F	.70 ± .02	5.8 ± .5	115 ± 2	61 ± 1	.38 ± .05	5.10 ± .71	11.4 ± .4	4.9 ± .4
8L:16D, 46 F	.63 ± .02	6.1 ± .5	108 ± 2	57 ± 1	.36 ± .04	6.30 ± .55	10.9 ± .3	5.0 ± .3
16L:8D, 65 F	.61 ± .02	5.7 ± .5	106 ± 2	56 ± 1	.36 ± .04	5.25 ± .56	10.7 ± .4	4.8 ± .4
8L:16D, 65 F	.54 ± .02	5.4 ± .5	99 ± 2	52 ± 1	.41 ± .04	6.10 ± .50	11.7 ± .3	5.3 ± .3
16L:8D, 88 F	.47 ± .02	6.2 ± .5	92 ± 2	46 ± 1	.38 ± .04	5.73 ± .54	11.3 ± .3	5.1 ± .3
8L:16D, 88 F	.33 ± .02	7.7 ± .5	79 ± 2	38 ± 1	.45 ± .07	6.26 ± .99	12.3 ± .6	5.6 ± .6

[1]Quality grade: 10 = low choice, 11 = average choice and 12 = high choice.
[2]Yield: 1 = high cutability; 5 = low cutability.

From Schanbacher, Hahn and Nienaber, J. Anim. Sci. 55:620-626, 1982.

Table 3.—Means (± SE) for performance and carcass traits of growing-finishing ram lambs exposed to a one-hour light flash (study 3)

Treatment	Average daily gain, lb/d	Feed efficiency, lb feed/ lb gain	Final wt, lb	Carcass wt, lb	Backfat thickness, in	Quality grade[1]	Yield grade[2]
Rams:							
16L:8D	.76 ± .02	4.6 ± .5	100 ± 1.5	48 ± .8	.21 ± .5	10.7 ± .1	3.2 ± .1
8L:16D	.92 ± .02	4.1 ± .5	112 ± 1.5	55 ± .8	.24 ± .5	10.8 ± .1	3.3 ± .1
7L:9D:1L:7D	.97 ± .02	4.2 ± .5	117 ± 1.5	54 ± .8	.22 ± .5	10.8 ± .1	3.2 ± .1

[1]Quality grade: 10 = low choice, 11 = average choice and 12 = high choice.
[2]Yield: 1 = high cutability; 5 = low cutability.

From Schanbacher and Crouse, Am. J. Physiol. 241:E1-E5, 1981.

Performance-Related Responses of Lambs to Changes in Environmental Temperature and Photoperiod

G. LeRoy Hahn, Bruce D. Schanbacher, John A. Nienaber[1]

Introduction

Performance of livestock is influenced by many environmental factors. The degree of influence varies with species, individuals within species and the duration and intensity of any specific environmental factor. Sheep have been shown to be particularly responsive to photoperiod, in terms of both reproduction and growth. Ambient temperature, especially hot weather, also has been shown to adversely affect sheep performance, particularly reproduction. However, such studies have generally examined the influences of photoperiod, temperature, etc., as independent factors rather than the interacting influences. Additionally, the time course of the responses to changes in the factors has been ignored.

The time course of animal responses to environmental factors can be an important management element whether the animals are in the natural environment with associated seasonal changes (e.g., daylength and general level of temperature) and weather events (e.g., temperature extremes and precipitation), as in the case of range animals, or in a modified environment with manipulated characteristics (e.g., artificial lighting and altered temperature), as in the case of intensively housed animals. The time course of performance responses in growing animals may also include compensatory growth, so that temporarily suppressed growth can be recovered in a subsequent time period. Compensatory growth in sheep after nutritional restrictions are removed has been well documented, but evidence is not clear for such growth in sheep subsequent to removal of other environmental stressors such as adverse thermal or light conditions.

Procedure

Thirty-six crossbred ram lambs born within an 18-day period in late May and early June were selected on the basis of weaning weight similarity from each of two groups (Finn-cross dams with Columbia or Suffolk sires). The resulting 72 unshorn lambs were randomly assigned to one of the six treatments shown in Table 1.

Two animals from the same sire group were placed in each 4 x 4 ft pen in controlled-environment chambers at MARC. All animals were provided water and pelleted feed *ad libitum* (feed contained 90.3 pct dry matter, 6.6 pct ash, 16.9 pct crude protein and 4,420 kcal/kg gross energy). The time course of the study was:

1) Adjustment Period (68°F; 16L:8D) for 2 weeks,
2) Pretreatment Period (68°F; 16L:8D) for 4 weeks,
3) Treatment Period (one of the Table 1 treatments) for 4 weeks, and
4) Post-treatment Period (68°F; 16L:8D) for 6 weeks.

Measured responses included individual animal body weight, pen feed and water intake, blood prolactin level, nonfasted heat production and carcass evaluation at slaughter (approximately 130 lb final weight).

Results

Body weight, feed intake, and prolactin data are summarized in Figures 1a and 1b. Results from the two sire groups and the 50° and 68°F treatments were combined, since no differences were obtained in responses from animals in these subgroups except for one set of prolactin measures. Least squares means adjusted for initial body weight are presented in Table 2. To obtain a measure of the level of heat stress induced by the 86°F treatment, measurements made during the 3rd and 4th week of treatment indicated a mean rectal temperature of 105.1° ± 0.5°F. Comparisons of heat production indicated animals in the 16L:8D photoperiod treatment were found to have higher rates of heat production than the 8L:16D treatment (2.94 *vs* 2.79 kcal/hr/kg body weight). Treatment temperature (50°, 68°, and 86°F) was not shown to have any significant effect on heat production. No differences were detected for any carcass traits measured at slaughter (dressing percentage, quality score, leg conformation score, 12th-rib fat and kidney fat).

Simple overall average food conversion and average daily gain for each 4-week treatment and 6-week post-treatment period are presented in Table 3 as a matter of interest.

Feed and Water Intake Response: Feed intake and water intake were not significantly different for the 50° and 68°F treatment groups during the 4-week treatment period. However, for 86°F animals, feed intake was depressed 21 percent and water intake increased 47 percent. The altered feed and water intakes for animals in the 86°F treatments were associated with an approximate 2.7°F rise in rectal temperature, based on normal temperature for sheep of 102.3°F. The impact of the elevated ambient temperature was rapid, with the animals exposed to 86°F showing a 6 percent decline in feed intake and a 62 percent increase in water intake during the first week of heat stress when compared with intake of the same group during the previous week at 68°F. Feed intake continued to decline during heat exposure (Fig. 1b), so that a significant temperature-week interaction was noted. There was also a related decline in water intake, but the high degree of variability in those data masked any significance. No effects of the 16L:8D and 8L:16D photoperiods were noted for feed or water intake during the full treatment period (Table 2); however, feed intake declined relatively more during the last week of treatment for the 8L:16D than for the 16L:8D animals (Fig. 1a,b).

As the treatment period ended and all animals returned to the post-treatment 68°F, 16L:8D base condition, the impact of the 86°F treatment temperatures on feed and water intake declined markedly, so that values for week 10 were approaching those of animals in the 50° and 68°F groups (Fig. 1a,b). The reduced feed intake resulting from the 86°F treatment persisted as a significant difference when compared with feed intake of animals in the 50° and 68°F groups for the first two weeks post-treatment; however, there were no differences in feed intake thereafter.

The post-treatment carryover effect of the 8L:16D photoperiod on feed and water intake was surprisingly persistent. For all three temperatures, a significant residual influence persisted throughout the 6-week post-treatment period, with both feed and water intake declining to levels considerably below those of the 16L:8D groups (15 pct lower for feed intake and 28-37 pct lower for water intake at the 6th week post-treatment). The increased heat production noted for animals in the 16L:8D groups is consistent with the metabolic activity associated with the higher level of feed intake and resultant higher growth rates for those groups.

As a matter of practical interest, it was noted that water intake increased linearly with body weight during the 14-week growth period for lambs on the 16L:8D photoperiod at 50° and 68°F. From an initial weekly water intake rate of 9.4 gal at a body weight of 62 lb, the rate of weekly water intake increased by about 0.1 gal/week per lb of increase in body weight.

Growth Response: Growth of lambs in the various treatment groups was strongly influenced by the feed intake response.

Average daily gain of lambs in all groups during the 68°F, 16L:8D photoperiod pretreatment period was about 0.88 lb/day and continued through the treatment period at or slightly above that rate for lambs at 50° and 68°F with 16L:8D photoperiods. The 86°F lambs showed a decline in growth rate to 0.66 lb/day or less after the 1st week of exposure and were growing less than 0.44 lb/day between the 3rd and 4th treatment weeks. Consequently, lambs at 86°F were significantly lighter after the 4-week treatment period than the 50° and 68°F groups. Although the initial post-treatment growth rate for these lambs (0.93 lb/day between weeks 9 and 10) exceeded that of the 50° and 68°F groups (0.83 lb/day), there was insufficient compensatory gain to overcome the 86°F growth suppression effects. As a results, body weights of the 86°F lambs remained significantly below those of the 50° and 68°F lambs for all post-treatment comparisons.

The 2- to 3-week delay in the effect of short days (8L:16D) on feed intake, noted earlier, was also reflected in the growth responses. There were no significant differences in body weights of lambs exposed to the short- and long-day photoperiod treatments during the overall 4-week treatment period, although short-day animals grew slower during the last week of treatment. This was most evident for short-day lambs at 86°F, which resulted in a temperature-photoperiod interaction during the treatment period only.

A slight compensatory effect on growth was noted the first 2 weeks after the short-day treatment, which also resulted in no initial carryover differences between the two daylength treatments. However, body weights of the short-day lambs were significantly less for the longer-term post-treatment periods (weeks 10-11 and 13-14).

For the overall 14-week growth period, lambs in the 50°F, 16L:8D treatment group had the highest average daily gain (0.87 lb/day) and the best feed conversion (4.87 lb feed/lb gain), followed closely by the 68°F, 16L:8D group. Optimal ambient temperatures for growing, *ad libitum* fed unshorn lambs in groups are considered to be in the range of 46-64°F, with nominal performance losses over the range of 32-75°F and an upper critical temperature at about 78°F. These results are consistent with those ranges. It is also of interest to note that the growth rates of lambs exposed to the 4-week, 86°F treatment were 18 percent and 10 percent lower for the long- and short-day groups, respectively, than for the comparable groups at 50°F. Associated feed conversion of the 86°F lambs were adversely affected by 8 percent and 6 percent, respectively, for the long- and short-day groups compared with lambs at 50°F.

The lack of any significant differences in gross carcass characteristics at slaughter is consistent with prior photoperiod studies which showed that the proportion of carcass fat was not increased even though the longer daylength resulted in increased gains. The present study also confirms the lack of a temperature effect on carcass measures.

Prolactin Response: In a previous study, we found that concentrations of prolactin were elevated by 16L:8D photoperiod when compared with 8L:16D, regardless of temperature (41°, 64°, or 88°F), and that a significant photoperiod-temperature interaction also occurred as a result of increased prolactin with increasing temperature for long days but not for short days. In the current study, initial prolactin values after start of the treatments (on the 1st day of treatment) did not differ from the 68°F, 16L:8D pretreatment values. By the 2nd week of treatment, however, prolactin values for long days (no change in photoperiod from pretreatment) increased for animals in all temperature treatments; no further increase was noted during the treatment period for any temperature. Overall prolactin levels for the long-day ram lambs during the treatment period were only 25-50 percent of those in ewe lambs in a prior 14-week study, but were consistent in the elevation noted for that 4-week treatment. Differences between responses to long and short daylengths at the treatment temperatures were not great enough to provide a significant photoperiod-temperature interaction during this 4-week treatment period, but prolactin did increase with temperature.

In the first two weeks (weeks 9 and 10) post-treatment, prolactin levels for 8L:16D lambs at all temperatures were depressed by 52 to 55 percent, compared with the long-day lambs. Significantly lower prolactin levels persisted in short-day lambs through week 12. The reason for the increase in prolactin levels with time (or body weight) for all treatment main effects with the single exception of the 8L:16D near-term post-treatment period is not apparent, but may have been associated with puberal or other biological events. Treatment temperature carryover effects on prolactin were not significant for any of the 2-week post-treatment periods considered.

Implications: These findings provide further evidence that the natural environment (e.g., elevated air temperatures or short days) can have significant adverse effects on growing lambs, and that compensatory performance is generally inadequate to overcome those effects. The reduced feed intake response to hot temperatures with subsequent growth suppression is a coping effort to maintain homeothermy. The role of short daylength remains unclear; the delayed but persistent effect after returning to long daylengths indicates an indirect inhibitory influence on undefined physiological mechanisms affecting feed intake. The results suggest that temperature modification or daylength manipulation in intensive housing can improve performance and may be worthy of further consideration for growing lambs.

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[1]Hahn and Nienaber are agricultural engineers, Agricultural Engineering Unit, and Schanbacher is a reproductive physiologist, Reproduction Unit, MARC.

Table 1.—Temperature and photoperiod treatments imposed

Treatment	Temperature	Photoperiod, h	No. Pens
1	50°F	16 Light: 8 Dark	6
2	50°F	8 L:16 D	6
3	68°F	16 L: 8 D	6
4	68°F	8 L:16 D	6
5	86°F	16 L: 8 D	6
6	86°F	8 L:16 D	6

Table 2.—Least-squares means for primary measures during and subsequent to treatment noted

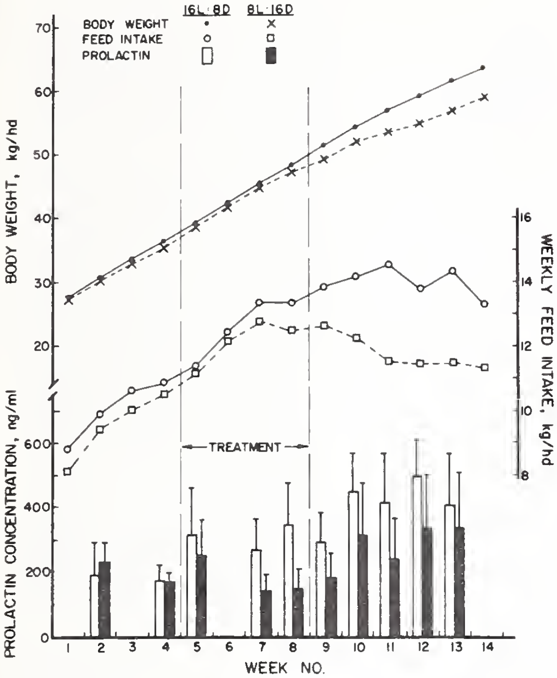
Period (weeks)	Treatment	Measurement: Body Weight (lb/hd)	Weekly Feed Intake (lb/hd)	Prolactin (ng/ml)	Weekly Water Intake (gal/hd)
Treatment (Wks 5-8)	50°F	^{1}95.9	^{1}27.3	^{1}216	^{1}11.1
	68°F	^{1}96.3	^{1}27.3	^{2}277	^{1}12.7
	86°F	^{2}91.5	^{2}21.4	^{2}269	^{2}17.4
	16L:8D	^{3}94.4	^{3}25.6	^{3}306	^{3}13.7
	8L:16D	^{3}94.8	^{3}25.1	^{4}202	^{3}14.0
Post-Treatment, Near-term (Wks 9-10)	50°F	^{1}114.4	^{1}29.1	^{1}292	^{1}14.8
	68°F	^{1}113.5	^{1}28.9	^{1}327	^{1}14.3
	86°F	^{2}103.8	^{2}25.4	^{1}303	^{1}14.5
	16L:8D	^{3}111.8	^{3}29.1	^{3}378	^{3}15.8
	8L:16D	^{3}109.6	^{4}26.7	^{4}236	^{4}13.2
Post-Treatment, Mid-term (Wks 11-12)	50°F	^{1}123.7	^{1}27.8	^{1}359	^{1}13.2
	68°F	^{1}123.0	^{1}28.9	^{1}382	^{1}12.7
	86°F	^{2}113.3	^{1}26.9	^{1}342	^{1}12.9
	16L:8D	^{3}122.6	^{3}30.4	^{3}433	^{3}15.0
	8L:16D	^{4}117.5	^{4}25.1	^{4}289	^{4}10.6
Post-Treatment, Final-term (Wks 13-14)	50°F	^{1}133.2	^{1}28.2	^{1}343	^{1}11.9
	68°F	^{1}132.0	^{1}27.6	^{1}402	^{1}12.4
	86°F	^{2}122.6	^{1}27.2	^{1}276	^{1}14.3
	16L:8D	^{3}132.7	^{3}30.0	^{3}366	^{3}14.8
	8L:16D	^{4}125.9	^{4}25.1	^{3}315	^{4}11.1

^{12}Different superscripts within a column denote significant differences for temperature main effect in each period ($P<.05$).
^{34}Different superscripts within a column denote significant differences for photoperiod main effect in each period ($P<.05$).

Table 3.—Feed efficiency and gain of lambs exposed to differing temperature and photoperiod environments

Treatment: °F	Treatment: Hrs L:Hrs D	Feed Conversion, lb feed/lb gain	Average Daily Gain, lb/hd
50	16:8	4.87	0.87
	8:16	4.96	0.75
68	16:8	5.03	0.84
	8:16	5.16	0.75
86	16:8	5.25	0.71
	8:16	5.26	0.68

a. Responses of lambs exposed to 50°F or 68°F ambient temperature (results combined) with 16L:8D or 8L:16D photoperiods.



b. Responses of lambs exposed to 86°F ambient temperature with 16L:8D or 8L:16D photoperiods.

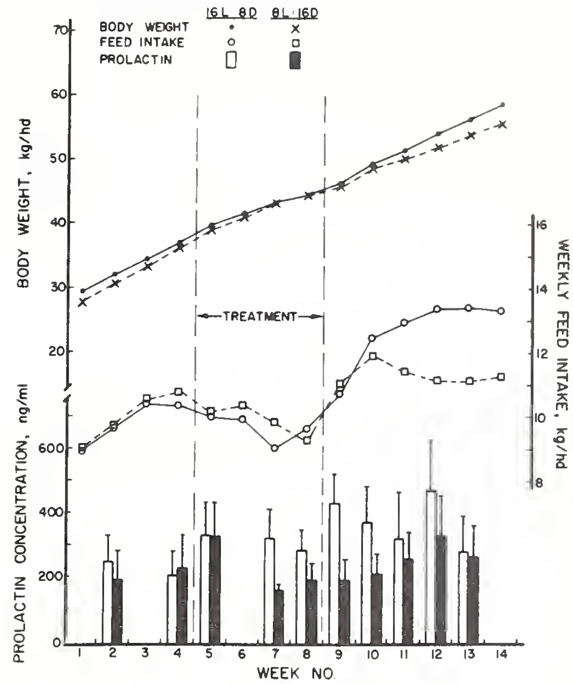


Figure 1—Body weight, feed intake and prolactin concentrations in the blood for growing ram lambs exposed during a 4-week treatment period to 50°, 68° or 86°F with either a 16L:8D or 8L:16D photoperiod (1 kg = 2.2 lb).

Sexual Development in Ram Lambs: I. Influence of Breed and Circulating Hormone Concentrations in the Blood

Sherrill E. Echternkamp and Donald D. Lunstra[1]

Introduction

Ram and ewe lambs that attain puberty by 7 months of age, and thus are fertile at the first breeding season after birth, significantly reduce the cost for producing replacement breeding animals. Also, they generally have increased lifetime production when compared to rams and ewes that do not become fertile until 18 months of age (second breeding season of life). Because age at puberty is heritable and puberty is manifested at a similar age in both ram and ewe lambs, the identification of measurable physiological variables to reliably assess puberty in ram lambs will provide for the selection of sires that attain puberty at the youngest age and the selection of ewe lambs sibling to ram lambs that attain puberty at a younger age. The result will be a reduction in age at puberty in subsequent generations.

The objective of this study was to evaluate relationships among testicular size, onset of spermatogenesis (puberty), and circulating concentrations of luteinizing hormone (LH) and testosterone in the blood of pre- and postpuberal rams from breeds of sheep that sexually mature at different ages and differ in breed prolificacy.

Procedure

Relationships among concentrations of LH and testosterone circulating in the blood, circumference of the scrotum (testicular size), diameter of the seminiferous tubules and onset of spermatogenesis (puberty) were evaluated in prepuberal Finnsheep (Finn), Finn x Rambouillet cross, Rambouillet and Suffolk ram lambs (breeds of sheep that sexually mature at different ages). Serial samples of blood (30-min intervals for 3 h) were collected from 5 rams/breed at 4, 6, 8, 10, 12, 14, 18, 22 and 26 weeks of age. Plasma from the blood was assayed for LH and testosterone by radioimmunoassays. Circumference of the scrotum at the widest part was measured at 10, 14, 18, 22 and 26 weeks. Biopsies of the testes were obtained from all rams at 14, 18, 22 and 26 weeks of age for microscopic evaluation of anatomical changes and stage of spermatogenesis within the seminiferous tubules of the testes.

Results

Mean concentration of LH in blood plasma (Fig. 1) was higher prepuberally (4 to 14 weeks of age) in Finn than in Finn x Rambouillet and Rambouillet lambs but not in Suffolk ram lambs. Concentrations of LH in blood plasma did not differ postpuberally (18 to 26 weeks of age) among breeds. Conversely, mean concentration of testosterone in blood plasma (Fig. 1) did not differ prepuberally among breeds but was higher postpuberally in Finn than in Finn x Rambouillet, Rambouillet or Suffolk rams. Circumference of the scrotum (Table 1) increased significantly between 10 and 26 weeks of age. Scrotal circumference did not differ among Finn, Finn x Rambouillet and Suffolk lambs but was significantly larger for Suffolk than Rambouillet lambs. Diameter of the seminiferous tubules (Table 2) within the testes also increased with age and was larger in Finn rams than in Finn x Rambouillet, Rambouillet or Suffolk rams. Spermatozoa were present within the seminiferous tubules of several Finn and Suffolk rams at 18 weeks (Table 3). The percentage of Finn, Finn x Rambouillet, Rambouillet and Suffolk rams having spermatozoa present within the seminiferous tubules was 80, 0, 0 and 40 at 18 weeks; 100, 60, 60 and 60 at 22 weeks; and 100, 100, 100 and 80 at 26 weeks, respectively. The positive correlations (Table 4) among means for diameter of seminiferous tubules, circumference of the scrotum and percentage of tubules/ram with spermatozoa indicated that size of the testes is an indicator of rate of sexual maturation (development) and that rams with larger testes generally attain puberty at a younger age. However, size of the testes is also correlated ($r = .95$) positively with body weight of the lamb, which may account for Suffolk ram lambs having larger testes but attaining puberty at an older age than Finn ram lambs. Thus, the use of testicular size or scrotal circumference to identify early sexually maturing rams among breeds that vary in mature body size may require an adjustment of testicular size for body size. Diameter of seminiferous tubules within testes of ram lambs at 14 to 18 weeks of age is a more reliable predictor of rate of sexual development but is not economically feasible in most commercial production systems.

The significant positive correlations (Table 4) among puberal concentrations of LH and testosterone in blood plasma, diameter of the seminiferous tubules and circumference of the scrotum suggested that increased circulating concentrations of LH prepuberally increased rate of sexual maturation. Likewise, suppression of circulating LH concentrations with progesterone implants in experiment II delayed growth and development of the testes in ram lambs.

In summary, the slower rate of sexual maturation in ram lambs with decreased circulating concentrations of LH and testosterone and LH pulse frequencies that occurred naturally or as a result of the progesterone implants (experiment II), suggested a positive functional relationship among LH secretion, testicular steroidogenesis and development and onset of spermatogenesis in prepuberal ram lambs. Ram lambs with larger testes at a specified age attained puberty and were fertile at a younger age than those with smaller testes. However, size of the testes was also influenced by breed differences in body size and, consequently, the use of testicular size as an index for spermatogenic development will require an adjustment for breed differences in mature body size. Diameter of the seminiferous tubules increased with age, paralleled increases in testicular size and concentrations of LH and testosterone circulating in the blood, and provided an index of spermatogenic development both within and among breeds.

Regardless of breed, the selection of ram lambs with a scrotal circumference of 32 to 33 cm at 6 months of age will identify early maturing ram lambs that will be fertile before 7 months of age.

[1]Echternkamp and Lunstra are research physiologists, Reproduction Unit, MARC.

Table 1.—Effect of breed on scrotal circumference in ram lambs at 10, 14, 18, 22 and 26 weeks of age

Breed	No.	Scrotal circumference (cm) at age: 10 weeks	14 weeks	18 weeks	22 weeks	26 weeks
Finn	5	16.4	20.3	[1]25.4	30.2	31.8
Finn x Rambouillet	5	14.3	[1]16.0	[2]20.4	[1]27.8	30.9
Rambouillet	5	15.6	[1]16.2	[2]20.3	[1]27.1	30.1
Suffolk	5	18.6	[2]21.5	[1]26.0	[2]32.6	32.6

[1,2]Values within a column with different superscripts differ significantly ($P<.05$).

Table 2.—Effect of breed on seminiferous tubule diameter in ram lambs at 14, 18, 22 and 26 weeks of age

Breed	No.	Tubule diameter (μm) [micrometers] at age: 14 weeks	18 weeks	22 weeks	26 weeks
Finn	5	[1]164.0	[1]199.4	[1]230.4	[3]231.8
Finn x Rambouillet	5	[2]104.0	[2]135.1	[2]184.0	196.6
Rambouillet	5	[2] 95.0	[2,3]123.5	[2]173.6	[4]178.0
Suffolk	5	124.0	[4]173.1	196.8	199.2

[1,2]Values within a column with different superscripts differ significantly ($P<.01$).
[3,4]Same except ($P<.05$).

Table 3.—Effect of breed on age at onset of puberty in ram lambs

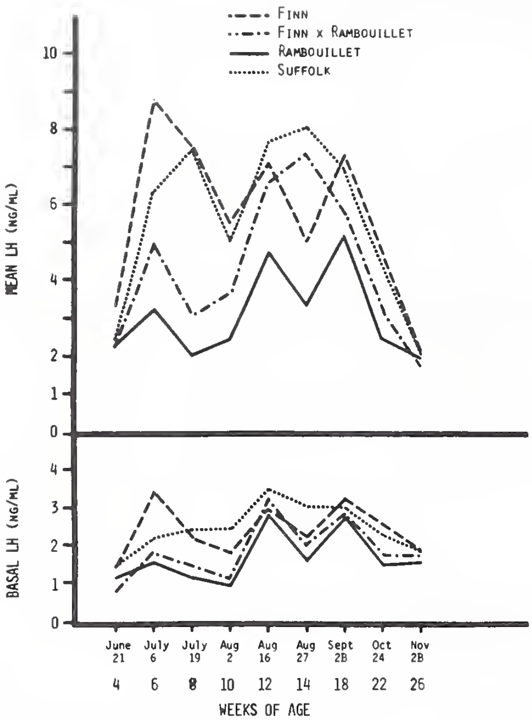
Breed	Presence of spermatozoa at age:[1] 14 weeks	18 weeks	22 weeks	26 weeks
Finn	0	39.1(4:5)	55.9(5:5)	52.0(5:5)
Finn x Rambouillet	0	0(0:5)	32.3(3:5)	48.9(5:5)
Rambouillet	0	0(0:5)	31.3(3:5)	34.4(5:5)
Suffolk	0	37.4(2:5)	49.9(3:5)	47.9(4:5)

[1]Percentage of seminiferous tubules that contained spermatids with elongated nuclei. Ratio of rams with spermatozoa is in parentheses.

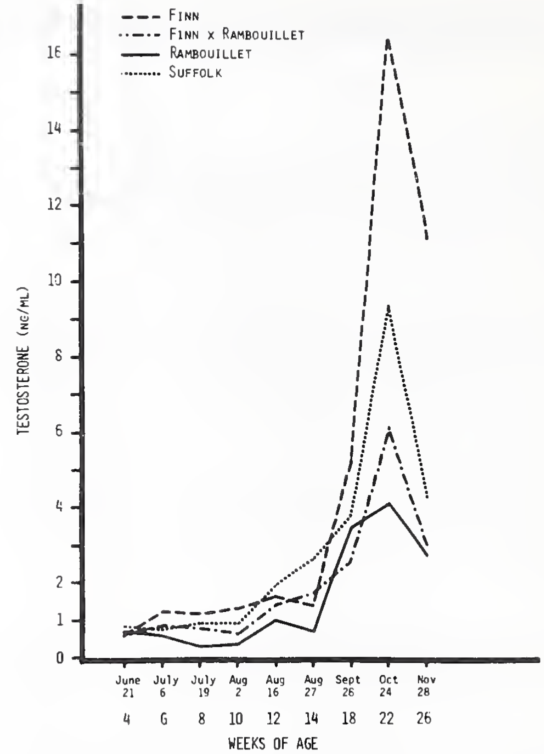
Table 4.—Relationships among prepuberal LH and testosterone (T) concentrations and testicular development

Items	Mean LH	Basal LH	Mean T	Tubule diameter at age: 14 weeks	18 weeks	22 weeks	26 weeks
Prepuberal mean LH		[1].74	[1].92	[1].67	[1].61	[2].52	[2].50
Prepuberal basal LH	[1].74		[1].84	[1].75	[1].75	[1].64	[1].66
Prepuberal mean T	[1].92	[1].84		[1].78	[1].75	[1].64	[1].61
Scrotal cir. at age:							
10 weeks	[1].60	[1].76	[1].75	[1].61	[1].65	[2].49	.38
14 weeks	[1].71	[1].88	[1].80	[1].80	[1].85	[1].64	[1].56
18 weeks	[1].60	[1].76	[1].69		[1].88	[1].65	[1].57
22 weeks	[2].47	[1].67	[2].49			[2].48	.35
Spermatogenic tubules at age:							
18 weeks	.45	.20	.49	.67	.75		
22 weeks	.43	[2].59	.42	[1].72	[2].64	[2].60	
26 weeks	.10	.46	.43	[2].49	[2].55	[2].54	[1].62

[1]$P<.01$.
[2]$P<.05$.



MEAN AND BASAL PLASMA LH CONCENTRATIONS FOR FINN, RAMBOUILLET, FINN x RAMBOUILLET AND SUFFOLK RAM LAMBS.



MEAN PLASMA TESTOSTERONE CONCENTRATIONS FOR FINN, RAMBOUILLET, FINN x RAMBOUILLET AND SUFFOLK RAM LAMBS.

Figure 1—Means for concentration of LH in blood plasma from 4 to 14 weeks of age were higher in Finn than in Finn x Rambouillet (P<.05) and Rambouillet (P<.01) ram lambs, but did not differ (P<.05) among the four breeds between 18 and 26 weeks. Concentrations of testosterone in blood plasma from 4 to 14 weeks of age did not differ (P>.05) among breeds but were higher (P<.05) from 18 to 26 weeks in Finn than in Finn x Rambouillet, Rambouillet and Suffolk rams.

Sexual Development in Ram Lambs: II. Influence of Gonadotropin Secretion

Sherrill E. Echternkamp and Donald D. Lunstra[1]

Introduction

Identification of the physiological mechanism(s) responsible for regulating initiation of puberty in sheep may provide an opportunity to manipulate age at puberty as well as to select ram and ewe lambs that attain puberty at a younger age, and, thus reduce the cost of producing replacement breeding stock. Results from the previous study (experiment I) indicated that ram lambs attaining puberty at younger ages had higher circulating concentrations of LH in the blood during the prepuberal period.

The objective of this study was to determine the relationship between circulating concentrations of LH in the blood and development of the testes in prepuberal Finnsheep (Finn) and Suffolk ram lambs by suppressing LH secretion for 4, 8 or 12 weeks. Suppression of LH secretion from the pituitary was accomplished by inserting subcutaneous progesterone implants at 2 weeks of age.

Procedure

Finn and Suffolk ram lambs were treated at 2 weeks of age with 12 progesterone-filled implants for periods of 4, 8 or 12 weeks. Serial samples of blood (30-min intervals for 3 h) were collected from 5 rams/breed within the four treatment groups at 4, 6, 8, 10, 12, 14, 18, and 22 weeks of age plus 1 and 2 weeks after implant removal for quantitation of LH and testosterone. Scrotal circumference was measured at 10, 14, 18, and 22 weeks of age, and a biopsy of the testes was obtained at 14, 18 and 22 weeks.

Results

Progesterone implants decreased mean concentration (ng/ml) of LH in blood plasma of ram lambs at 6 (1.1 vs 6.2), 8 (1.6 vs 10.9), 10 (1.1 vs 5.6), 12 (2.7 vs 9.6), but not at 14 (5.4 vs 8.2) weeks of age when compared to control rams (Fig. 1). Mean concentration of testosterone (Fig. 1) in blood plasma was also decreased during the progesterone treatment period. Circulating concentrations of both LH and testosterone increased in the blood within 1 week after removal of progesterone implants. Scrotal circumference (Table 1) was subsequently reduced at 10 and 14 weeks of age by the progesterone treatment. Diameter of the seminiferous tubules (Table 2) was reduced in progesterone-treated rams at 14 weeks of age and was inversely related to duration of the progesterone treatment. Puberty was delayed 4 or more weeks in rams implanted with progesterone for 8 or 12 weeks relative to 4 weeks or control (Table 3). Finn rams had significantly larger diameters for seminiferous tubules but smaller testicular size in comparison to Suffolk rams in experiment II, whereas the two breeds did not differ in experiment I. Lack of progesterone treatment effects on testicular development at 18 and 22 weeks of age suggested that compensatory growth occurred after removal of the progesterone implants to overcome the inhibitory effects of progesterone. Again, the slower rate of sexual maturation in ram lambs with decreased circulating concentrations of LH and testosterone and LH pulse frequencies resulting from the progesterone implants suggested a positive functional relationship among LH secretion, testicular steroidogenesis and development and onset of spermatogenesis in prepuberal ram lambs.

[1]Echternkamp and Lunstra are research physiologists, Reproduction Unit, MARC.

Table 1.—Effect of progesterone implants in prepuberal ram lambs on scrotal circumference at 10, 14, 18 and 22 weeks of age[1]

Breed	Progesterone treatments[2]	No.	Scrotal circumference (cm) at age: 10 weeks	14 weeks	18 weeks	22 weeks
Finn	Control	5	[35]18.5	21.6	26.5	31.8
	4-wk implant	5	15.8	19.0	24.9	30.1
	8-wk implant	5	[6]14.7	19.7	26.7	31.4
	12-wk implant	5	[4]14.1	18.5	25.8	29.9
	Mean	20	[7]15.8	[7]19.7	26.0	[7]30.8
Suffolk	Control	5	19.3	[5]26.3	30.1	35.2
	4-wk implant	5	18.3	[4]20.2	25.9	32.1
	8-wk implant	5	16.7	[6]21.6	26.0	34.3
	12-wk implant	5	17.2	[6]21.2	25.4	34.1
	Mean	20	[8]17.9	[8]22.3	26.9	[8]33.9

[1]Least-squares means.
[2]Ram lambs received sham implants (control) or progesterone implants at 2 weeks of age for the indicated duration.
[34]Treatment means differ within age and breed (P<.01).
[56]Treatment means differ within age and breed (P<.05).
[78]Breed means differ (P<.01).

Table 2.—Effect of progesterone implants in prepuberal ram lambs on seminiferous tubule diameter at 14, 18 and 22 weeks of age

Breed	Progesterone treatments[2]	No.	Tubule diameter (μm) at age: 14 weeks	18 weeks	22 weeks
Finn	Control	5	[3]156.9	192.2	[3]231.6
	4-wk implant	5	140.4	182.5	[4]200.1
	8-wk implant	5	129.3	192.5	222.7
	12-wk implant	5	[4]116.3	176.0	208.9
	Mean	20	[5]135.7	[7]185.8	[5]215.8
Suffolk	Control	5	[3]158.6	178.0	204.2
	4-wk implant	5	[4]117.4	167.1	192.0
	8-wk implant	5	[4]111.0	168.1	201.0
	12-wk implant	5	[4]105.8	163.0	209.3
	Mean	20	[6]123.2	[8]169.1	[6]201.6

[1]Least-squares means.
[2]Ram lambs received sham implants (control) or progesterone implants at 2 weeks of age for the indicated duration.
[34]Treatment means differ within age and breed (P<.01).
[56]Breed means differ (P<.01).
[78]Breed means differ (P<.05).

Table 3.—Effect of progesterone implants in prepuberal ram lambs on onset of puberty

Breed	Progesterone treatments	Presence of spermatozoa at age:[1] 14 weeks	18 weeks	22 weeks
Finn	Control	19.7 (1:5)	37.8 (4:5)	45.1 (5:5)
	4-wk implant	0 (0:5)	31.0 (4:5)	31.1 (5:5)
	8-wk implant	0 (0:5)	0 (0:5)	55.4 (5:5)
	12-wk implant	0 (0:5)	0 (0:5)	35.9 (5:5)
Suffolk	Control	0 (0:5)	37.3 (4:5)	27.2 (4:5)
	4-wk implant	0 (0:5)	38.3 (2:5)	20.7 (3:5)
	8-wk implant	0 (0:5)	0 (0:5)	48.6 (2:5)
	12-wk implant	0 (0:5)	0 (0:5)	38.1 (5:5)

[1]Percentage of seminiferous tubules that contained spermatids with elongated nuclei. Ratio of rams with spermatozoa is in parentheses.

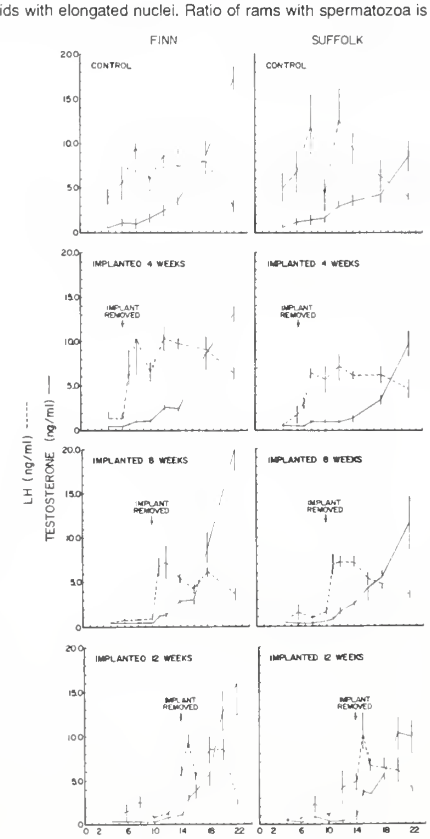


Figure 1—Mean concentrations of LH and testosterone in blood plasma of Finn (left panels) and Suffolk (right panels) ram lambs that were untreated (controls) or implanted with progesterone-filled capsules for a duration of 4, 8 or 12 weeks. The progesterone implants decreased (P<.01) mean concentrations of LH in plasma at 4, 6, 8, 10 and 12 weeks of age but not (P>.05) at 14 weeks.

Immunocastration: A Nonsurgical Approach

Bruce D. Schanbacher[1]

Introduction

Castration has been used to produce animals with reduced sexual and/or aggressive behavior. These animals are easier to manage, fatten more readily and have the potential of reaching the market place at a younger age. Conventional methods of castration, however, have certain disadvantages. in addition to the initial trauma of surgical castration, secondary consequences (e.g., hemorrhage and infection) can contribute to temporary as well as prolonged set backs on the efficiency of animal production. Alternate methods of castration designed to alleviate the stress and discomfort associated with conventional procedures are, therefore, of interest. Because immunization against luteinizing hormone-releasing hormone (LHRH) results in testicular atrophy and decreased testosterone secretion in laboratory animals, the present study was conducted to evaluate the effects of active immunization of young ram lambs against LHRH on testicular function and on their subsequent growth and development.

Procedure

Forty-eight crossbred lambs were weaned at approximately 8 weeks of age and randomly assigned to four treatment groups. Group 1 lambs were left intact; Group 2 lambs were immunized against bovine serum albumin (BSA); Group 3 lambs were immunized against LHRH: human serum albumin; and Group 4 lambs were surgically castrated. Antibody titers, testes weights and blood endocrine parameters are given in Table 1 for these lambs, whereas performance and carcass traits are given in Table 2.

Results

Mean LH and FSH concentrations were elevated in castrate lambs and decreased in LHRH-immunized lambs when compared to intact and BSA-immunized lambs. In contrast, serum testosterone concentrations were low or nondetectable in both surgically castrated and LHRH-immunized lambs. Not only were mean serum concentrations of LH, FSH and testosterone low in LHRH-immunized lambs, but these hormones failed to respond to a 250 ng LHRH challenge injection. This finding suggests either that excess neutralizing antibodies are present in the LHRH-immunized lamb or that the pituitary-testicular endocrine axis is unable to respond to an acute challenge. Testes weights were small and sperm were absent in both testes and epididymides of LHRH-immunized lambs.

Intact and BSA-immunized lambs had a faster rate of gain than castrate or LHRH-immunized lambs, and these gains were reflected in group means for final weight and carcass weight. LHRH-immunized lambs required the most feed for each unit of gain while intact and BSA-immunized lambs required the least for each unit of gain. Although surgically castrated lambs had greater backfat thickness and reduced retail yield, carcass attributes were not consistently affected by treatment.

The marked inhibition of LH and FSH in LHRH-immunized lambs is consistent with the hypothesis that production of high titer antisera against LHRH would neutralize endogenous LHRH and block the stimulatory action of this hormone on gonadotropin secretion by the pituitary and testosterone secretion by the testes. Inhibition of testicular growth and sperm production would follow, resulting in a "castrate like" condition in LHRH-immunized lambs.

In summary, immunization against LHRH alleviates the problem typically associated with surgical castration and, therefore, may provide an appropriate alternative to conventional castration techniques. The success reported herein provides incentive for further investigations so that management of domestic animals could become more humane and efficient.

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Table 1.—Antibody titers, paired testes weights, serum concentrations of LH, FSH and T and LH-T responses to 250 ng LHRH in ram lambs immunized against LHRH[1]

Treatment	Antibody titers (pct)	Paired testes wt (g)	Serum LH (ng/ml)	Serum FSH (ng/ml)	Serum T (ng/ml)	Acute response to exogenous LHRH: LH (ng/ml)	Acute response to exogenous LHRH: T (ng/ml)
Intact	—	342 ± 21	2.0 ± 0.2	101 ± 9	2.4 ± 0.5	11.4 ± 2.4	5.1 ± 1.1
BSA	[2]<3.4	318 ± 21	2.1 ± 0.2	81 ± 10	2.3 ± 0.3	11.2 ± 1.5	5.2 ± 1.5
LHRH	[3]40 ± 5	[4]68 ± 26	[4]0.6 ± 0.04	[4]56 ± 3	[4]0.3 ± 0.1	[4]0.8 ± 0.06	[4]0.4 ± 0.1
Castrate	—	—	[4]12.8 ± 2.7	[4]376 ± 28	[4]0.3 ± 0.1	[4]23.1 ± 4.1	[4]0.3 ± 0.1

[1]Values are means ± SE.
[2]Percentage of ^{125}I-LHRH binding in serum diluted 1:10^2.
[3]Percentage of ^{125}I-LHRH binding in serum diluted 1:10^4.
[4]P<0.01, significantly different from intact group.

Table 2.—Performance and carcass traits of intact ram lambs, lambs immunized against BSA and LHRH and castrate lambs[1]

Treatment	Avg. daily gain (lb/day)	Feed efficiency (lb feed/lb gain)	Final wt (lb)	Carcass wt (lb)	Backfat thickness (in)	Kidney-pelvic fat (pct)	Quality grade[2]	Yield grade[3]
Intact	0.91	5.3	139.8	70.1	0.26	2.0	11.5	3.2
BSA	0.92	5.3	140.9	69.4	0.26	2.3	11.2	3.3
LHRH	[4]0.69	[4]6.2	[4]121.9	[4]63.1	0.23	1.9	11.0	3.2
Castrate	[4]0.78	[4]5.6	[4]133.1	66.8	[4]0.41	2.4	10.8	[4]4.4
SE (pooled)	±0.04	±0.2	±0.4	±2.0	±0.04	±0.2	±0.3	±0.3

[1]Values are least squares means.
[2]Quality grade: 10 = low choice; 11 = avg. choice; 12 = high choice.
[3]Yield grade: 1 = high cutability; 5 = low cutability.
[4]P<0.05 (significantly different from intact group).